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EVALUATION OF REPRODUCTIVE PHENOLOGY AND ECOLOGY OF EASTERN WILD TURKEY (MELEAGRIS GALLOPAVO SILVESTRIS) ACROSS THE SOUTHEASTERN UNITED STATES

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EVALUATION OF REPRODUCTIVE PHENOLOGY AND ECOLOGY OF EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) ACROSS THE SOUTHEASTERN UNITED STATES

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DEDICATION

I would like to dedicate this thesis to my brother, my parents, and all of my family and friends. Without all of your love and support I could not have been motivated to complete this journey. I would like to thank my brother Dylan for always being by the phone and accepting my calls and talking sense into me. Also, for always supplying me with high quality hunting and trapping opportunity when I would fly numerous places to hunt with him. I would like to thank my dad and grandfather. Without your support and passion for trapping, I would never had an understanding for wildlife that I have developed. The lessons that you have taught me are priceless. Lastly I would like to thank my mom. You have taken me all over this world and supplied me with the best opportunities to succeed in life. You always made sure to support me whether it was skateboarding, music, or this crazy wildlife career path. I appreciate how you have hung with me and always given your support. Thank you all and I love you.

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ABSTRACT

Avian reproduction is known to be a driver of population dynamics across species and systems. Behavioral decisions during incubation such as habitat selection and nest attentiveness are thought to affect nest success. The incubation process is a costly period during which individuals are sedentary and must balance survival with reproductive success and overall fitness. Current understanding of Eastern wild turkey incubation behavior provides a limited view of the incubation period. Using GPS data collected from Eastern wild turkeys (n = 220), I evaluated nest fate as it relates to recess frequency, distance travelled during recess, and habitat selection during the incubation period. My results differed from previous studies, whereas I show that individuals made daily recesses until the final day of the incubation period. I observed that individuals that made frequent long distance recess movements had a greater chance of having a successful nest, opposed to individuals that made infrequent recesses and moved short distances. My results suggest behavioral decisions are influencing trade–offs during the incubation period to reduce the risk of predation, specifically adjusting the amount of time an individual spends on and off the nest.

Developing decision–making tools that adequately and accurately describe the biological system are important to develop sound wildlife management strategies. Models that use regression analysis are important as they provide insight on a specific topic within the system. However, it is equally important to incorporate findings from a suite of studies into a conceptual framework in order to understand biological relationships within the system. Bayesian belief network allows me to integrate multiple studies into a meaningful biological framework. Constructing a framework based on biological causality, I evaluated how vegetation characteristics at the nest site, landscape attributes within the recess range, and behavioral

decisions are linked within the system and collectively influence nest fate. I found that nest fate was influenced by incubation range, nest attentiveness, and ground cover. However, these variables were also influenced by underlying vegetation characteristics and landscape attributes. My conceptual model suggest that Bayesian belief networks are a graphical model that identifies uncertainty and allows for identification and enumeration of measurable variables in a more biological meaningful way.

CHAPTER 1. INTRODUCTION

The wild turkey (*Meleagris gallopavo*) is the largest galliform in North America and is widely distributed across the continent. In the 1900s, due to unregulated hunting and lack of sustainable habitat conservation practices, the wild turkey was almost extirpated from the United States. Extensive restoration efforts by state, federal, and non–profit organizations brought the wild turkey back to sustainable population levels. Wild turkey are the second most hunted species in the United States with approximately 2.6 million hunters (21%) targeting wild turkeys (USFWS 2006). Ensuring a sustainable population is important to retain hunter numbers, which in turn provide a contribution of approximately $1.6 billion to the nation's economy (USFWS 2006). However, across the southeastern United States there has been a decline in Eastern wild turkey (*Meleagris gallopavo silvestris*, hereafter, wild turkey) populations. Managers and researchers are challenged with identifying drivers of population decline in order to maintain a sustainable population of the species, and gain the economic benefits from the resource to support further conservation efforts.

Wild turkey are a ground-nesting uniparental species that inhabit the southeastern United States. The incubation period ranges from 28–30 days during the months of March-July (Healy 1992). During this time, the female wild turkey is restricted to a range surrounding the nest site (Healy 1992, Conley et al. 2015). Often, proximate drivers of reproductive success are frequently tied to vegetative conditions within some proximity of the nest site (Ghalambor and Martin 2002, Batary and Baldi 2004). Studies on wild turkeys suggest nest site selection and vegetative characteristics at the nest to be the primary driver of reproductive success (Badyaev et al. 1996, Chamberlain and Leopold 200). Potential drivers of nest success have been linked to vegetative communities surrounding the nesting location, specifically with increasing visual obstruction and

ground cover at the nest site (Badyaev 1995, Conley et al. 2015, Streich et al. 2015, Yeldell et al. 2017, Wood et al. 2018). However, these studies on vegetative communities find significance with nest site selection but no relationship to success of the nest (Kilburg et al. 2014, Yeldell et al. 2017).

Recognizing how behaviors drive the scale of habitat selection is critical to further management strategies and provide focus on how to maintain turkey populations (Collier and Chamberlain 2011). Previous work believed female turkeys sampled habitats during the pre-incubation period to identify nest sites (Chamberlain and Leopold 2000). However, recent evidence indicates, female turkeys do not select vegetation communities for nesting until almost immediately prior to nesting (Conley et al. 2016). Thus, selection processes for nest sites must work at a different temporal scale. During the incubation period Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) were restricted to an average area of 1.46 ha during the incubation period (Conley et al. 2015). The incubation range, being the area available to a turkey to use, thus must provide habitat that encompasses limiting factors needed by the individual while incubating (Orians and Wittenberger 1991). Hence, habitat selection should be driven by behavior decision made during the incubation period.

In order to survive, recess movements are made from the nest site to defecate, drink, and forage (Williams et al. 1971, Green 1982, Martin et al. 2015, Conley et al. 2016). Wild turkeys were thought to recess on average once a day for approximately an hour (Williams et al. 1971, Green 1982, Spohr 2001). Movements away from the nest location for Rio Grande wild turkey in Texas were found to take place frequently early in incubation and less frequently as the individual neared the hatch date (Conley et al. 2015). Although these behaviors have been

documented in the literature, an evaluation of have incubation recess behavior is related to nest success is unknown.

Studies on wild turkeys have suggested that habitat selection, vegetative conditions, and behavioral factors may all influence nest fate. Throughout the literature we lack models that provide biological interactions that are important to develop concrete management strategies. Current models use simulation and regression analyses that hold variables constant and reduce the understanding of the complete system (Porter et al. 1990, Roberts et al. 1995, Alpizar-Jara et al. 2001, Norman et al. 2001, Pollentier et al. 2014a, Pollentier et al. 2014b). Using population models that integrate multiple facets of data can allow us to provide a more biologically relevant meaning to the system (Marcot et al. 2001, Pielke Jr 2003, Borsuk et al. 2004, Bashari et al. 2008).

Causal models are useful in developing connections between environmental factors and behaviors that influence the population dynamics of a species (Marcot et al. 2001). In other words, think of causal models as understanding the cause and effects each parameter has within a biological system on one another. Bayesian belief network approach allows us to create graphical models that represent causal linkages within the system (Charniak 1991, Marcot et al. 2001, Borsuk et al. 2004, McNay et al. 2006, MacPherson et al. 2018). These types of models are built on probabilistic frameworks that incorporate and evaluate uncertainty within parameter estimates and allow us to make predictions based on causal linkages within the system (Marcot et al.). Using a Bayesian belief network we are able to create linkages between vegetative communities, habitat selections, and behavioral processes during incubation to further our understanding of complex relationship interactions.

Using the advancements of GPS transmitters for wild turkey, I evaluated incubation behavior of wild turkeys and developed a conceptual model for wild turkey reproduction that evaluates multiple factors identified in the literature. In this thesis I present data from 8 study sites across the Southeastern United States located in Georgia, Louisiana, South Carolina, and Texas. Chapter 2 describes incubation behavior on all 8 sites and the impact on nest survival. In Chapter 3 I created a conceptual framework for how multiple causal drivers (vegetation communities, habitat selection, and behavior) affect wild turkey biology. Thus, the goal was to develop a conceptual framework for the understanding of wild turkey reproductive biology in southeastern United States.

CHAPTER 2. DOES INCUBATION RECESS BEHAVIOR INFLUENCE NEST SUCCESS OF UPLAND GROUND-NESTING BIRDS?

2.1. Introduction

Annual reproduction is the primary driver of avian population dynamics across a wide variety of species and systems (Martin 1995). Identifying factors influencing variability in reproductive success is central to improving understanding of population dynamics (Ghalambor and Martin 2002, Martin 2002). Reproductive activities are known to be expensive to avian species, resulting in periods of high predation risk, reduced energy acquisition, and impacts to embryonic development (Skutch 1962, Fontaine and Martin 2006, Deeming and Reynolds 2015). Hence, birds use a wide array of behavioral strategies during incubation to ensure nest success in dynamic landscapes (Deeming 2002).

Ground–nesting upland birds are sedentary during incubation, which limits foraging opportunities and potentially exposes individuals to elevated predation risk (Skutch 1962, Deeming and Reynolds 2015). Vegetative communities surrounding the nest site have been poised to reduce predation risk by increasing concealment (Deeming et al. 2002). Evaluations of likely drivers of reproductive success have regularly focused on vegetative conditions at the nest site (Martin 1993, Ghalambor and Martin 2002, Batary and Baldi 2004), as vegetation is thought to mitigate predation risk and influence nest site selection (Orians and Wittenberger 1991). Thus, the distribution of vegetation and resources around nest sites may have fitness consequences to females (Jones 2001), which are manifested via behavioral decisions during incubation. Therefore, behavioral activities undertaken during incubation may mitigate risk of nest loss (Martin 1993, Deeming 2002).

Incubation recesses allow females to forage while maintaining appropriate egg temperatures (Deeming 2002). However, movements associated with recesses may increase predation risk to both the female and nest (Webb 1987, Martin 2002), therefore, the distribution of resources within an accessible landscape during incubation should influence frequency of individual recess movements. Currently, the consequences of recess movements on nest survival of ground–nesting upland birds are generally unknown (Orians and Wittenberger 1991, Jones 2001), but there is evidence suggesting that activities such as recess bout frequency can impact reproductive success (Conway and Martin 2000). Thus, linking recess behavior during incubation with conditions of the surrounding landscape may provide insight into individual reproductive success (Aldrich and Raveling 1983, Smith et al. 2012).

The Eastern wild turkey (*Meleagris gallopavo silvestris*; hereafter, turkey) is a ground nesting uniparental galliform widely distributed across North America. Duration of incubation ranges from 26–30 days during March–July (Healy 1992) and during incubation, females are restricted to an incubation range around the nest site (Healy 1992, Conley et al. 2015). Nest–site selection and vegetative characteristics at the nest site have historically been considered the primary driver of reproductive success for wild turkeys (Badyaev et al. 1996, Chamberlain and Leopold 2000), but contemporary works have noted that vegetative conditions at nest sites may have limited importance to nest success (Byrne and Chamberlain 2013, Conley et al. 2015, Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017).

Recently, Conley et al. (2015) hypothesized that recess movements by incubating wild turkeys may have a greater impact on nest survival and reproductive success than previously thought. Incubation recesses by wild turkeys are believed to be geared towards ensuring that incubating females can defecate and forage away from nest sites (Williams et al. 1971, Green

1982, Martin et al. 2015, Conley et al. 2016), but recesses have rarely been accurately documented in the field (Williams et al. 1971, Conley et al. 2015). Notably, the extant literature on incubation recess behaviors by wild turkeys is largely based on < 10 visual observations of individuals either leaving or returning to nest sites (Williams et al. 1971). As incubating female turkeys must balance recess movements with increased predation risk, there is potential that recess movements and resources selected by females during recesses could impact nest success.

However, understanding of how incubation recess behaviors are related to nest success is an unknown, yet potentially important aspect of collective understanding of wild turkey reproductive ecology. My objectives were to 1) examine recess movements of incubating female Eastern wild turkeys and determine if these movements influenced nest success, and 2) evaluate habitat conditions that relate to recess movement frequency and incubation range sizes.

2.2. Study Area

I conducted research on 7 different study sites (Figure 2.1.). In South Carolina, I conducted research on 3 contiguous wildlife management areas (WMA; Webb, Hamilton Ridge, and Palachucola; hereafter Webb WMA Complex), all managed by the South Carolina Department of Natural Resources (SCDNR). The Webb WMA Complex was dominated by longleaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), and slash pine (*P. elliottii*) forests with hardwood stands along riparian corridors, and expanses of bottomland hardwood wetlands. Prescribed fire was applied on an approximately 3–5 year return interval. For a detailed description of site conditions on the Webb WMA Complex see Wightman et al. (2018).

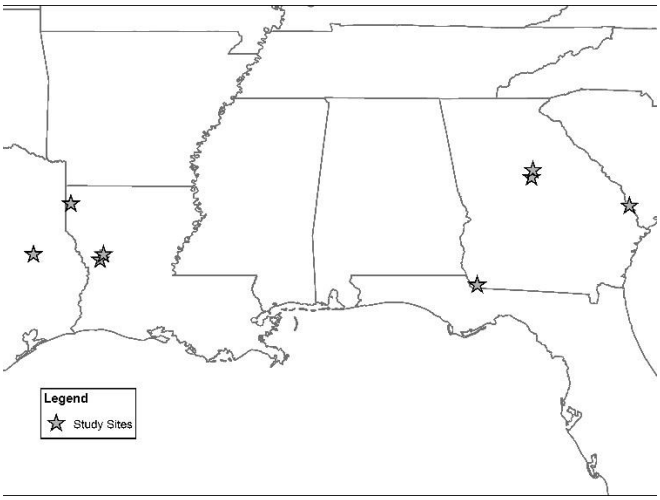

Figure 2.1. Map of study sites and ecoregions of the southeastern United States where incubation recess behaviors were evaluated for female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during 2014–2017.

In Georgia, I conducted research on 3 sites; Cedar Creek, B. F. Grant, and Silver Lake Wildlife Management Areas. The Silver Lake Wildlife Management Area (SLWMA), located in southwest Georgia, was owned and managed by the Georgia Department of Natural Resources-Wildlife Resources Division (GADNR). SLWMA was dominated by mature pine forests and forested wetlands. Overstory species were predominately longleaf pine, loblolly pine, slash pine, oaks, and sweetgum (*Liquidambar styraciflua*). Prescribed fire was applied on an approximately 2–3 year return interval. For a detailed description of site conditions on SLWMA, see Wood et al. (2018).

B. F. Grant Wildlife Management Area was owned by the Warnell School of Forestry and Natural Resources at the University of Georgia, and was managed jointly by the GADNR and the Warnell School. B. F. Grant was dominated by loblolly pine stands, agricultural lands, mixed hardwood and pine forests, and hardwood lowlands containing mostly oaks (*Quercus* spp.), sweetgum, and hickory (*Carya* spp.). Agricultural lands were mostly grazed mixed fescue (*Festuca sp.*) fields and hay fields planted for rye grass (*Lolium sp.*). Cedar Creek Wildlife

Management Area was owned by the U. S. Forest Service (USFS) and managed in partnership with GADNR. Cedar Creek was composed primarily of loblolly pine uplands, mixed hardwood and pine forests, and hardwood lowlands of similar species composition as B. F. Grant. Prescribed fire was applied on an approximately 3–5 year rotation.

In Louisiana, I conducted research on the Kisatchie National Forest (KNF) and Peason Ridge WMA in west-central Louisiana, and on private lands in western Caddo Parish. The KNF was owned and managed by the USFS, whereas Peason Ridge WMA was jointly owned by the USFS and the United States Army. Both areas were composed of pine-dominated forests consisting of loblolly pine, longleaf pine, slash pine, hardwood riparian zones, and forested wetlands, with forest openings, utility right-of-ways, and forest roads distributed throughout. Prescribed fire was applied on an approximately 3–5 year return interval. For a detailed description of site conditions on KNF, see Yeldell et al. (2017). I worked in western Caddo Parish primarily north of Greenwood, Louisiana, with most of the landscape comprised of industrial forests dominated by loblolly pine stands of varying seral stages.

In Texas, I conducted work on the Angelina National Forest (ANF) in east-central Texas. The ANF was owned and managed by the USFS and was pine dominated with hardwood riparian zones. Forest stands on the ANF were dominated by loblolly pine, longleaf pine, sweetgum, and oaks. Prescribed fire was applied on approximately 1–5 year return interval.

2.3. Methods

I captured turkeys using rocket nets baited with cracked corn during January–March 2014–2017. I identified sex and determined age of captured individuals based on presence of barring on the ninth and tenth primaries (Pelham and Dickson 1992). All individuals were given a numbered, riveted aluminum tarsal band and radio-tagged with a backpack–style GPS–VHF

transmitter (Guthrie et al. 2011) produced by Biotrack Ltd. (Wareham, Dorset, UK). I programmed transmitters to take 1 location nightly (23:58:58), and hourly locations between 0500 and 2000 until the battery died or the unit was recovered (Cohen et al. 2018). I released turkeys at the capture location immediately following processing and any individual who died within 3 weeks of release was considered a post-release mortality and was removed from subsequent analysis.

In 2016, wild turkeys were captured in Louisiana and translocated to Caddo Parish. Upon capture, each individual was given a numbered, riveted aluminum tarsal band and radio-tagged with a backpack–style GPS–VHF transmitter. I programmed the units to record 3 locations daily (0800, 1600, 2400 local time). Turkeys were placed in separate transport boxes, driven to the release sites, and immediately released within 1 to 3 hours of capture (Cohen et al. 2015). Furthermore, during 2016 wild turkeys were captured in Iowa and West Virginia and translocated to ANF, whereas in 2017, wild turkeys were captured in Iowa and Missouri and translocated to ANF. I programmed GPS transmitters on birds translocated to ANF to collect hourly locations (0700 to 1800), along with a roost location at 0000.

I monitored live-dead status daily during the reproductive season using handheld Yagi antennas and R4000 (Advanced Telemetry Systems, Inc., Isanti, MN) or Biotracker receivers (Biotrack Ltd., Wareham, Dorset, UK). I downloaded GPS locations ≥ 1 per week via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). I viewed GPS locations and determined incubation when female locations became concentrated around a single point for several days (Collier and Chamberlain 2011, Conley et al. 2015, Yeldell et al. 2017, Wood et al. 2018). Nesting females were not disturbed or flushed from nest sites during monitoring, but instead were live-dead checked daily via VHF from a distance of > 20 m. All

turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Protocol No. A2014 06-008-Y1-A0 and A3437-01) and the Louisiana State University Agricultural Center (Protocol No. A2015-07).

Following Yeldell et al. (2017), after nest termination I located nest sites to determine nest fate and confirm the precise nest location for future analyses. Wild turkeys require approximately 27 days of continuous incubation to complete nesting (Williams et al. 1971), but incubation can vary from 25 to 29 days (Healy and Nenno 1985). Therefore, I considered a nest to have been depredated or abandoned if the female left the nest ≤ 25 days into incubation, or if only intact eggs, no eggs, or egg fragments were found at the nest bowl.

Females will frequently roost away from the nest site the night before initiating incubation (Conley et al. 2016), so I censored data from the first day that incubation was confirmed to occur so that I excluded movements potentially associated with laying of the last egg in the clutch from my analysis. Additionally, I censored the day of hatch and the previous day of incubation for successful nests to ensure that movements potentially related to newly hatched broods would not influence inferences related to recess behaviors.

There is no published protocol for quantifying what constitutes an incubation recess by wild turkeys. Previous work by Williams et al. (1971) has been widely cited, but inferences from Williams et al. (1971) were based on 10 recess events with an average of 1.5 hours per recess. Furthermore, incubating females were irregularly monitored during the incubation period, and data were interpolated graphically for some of recesses described by Williams et al. (1971). Hence, I sought to develop a rigorous, standardized method to identify recess movements using spatial data. First, based on previous GPS error evaluations (Guthrie et al. 2011), I buffered each nest site by 27 m as per Collier et al. (2019). I then classified any

locations > 27 m away from the known nest location as a recess movement, and considered all locations not at the nest but < 27 m from the nest as incubation and not recess movements. I defined a single recess movement as an individual leaving and then returning to the nest at a later time (e.g., ≥ 1 location outside of the 27 m buffer). I measured both daily frequency of recess movements and distance and time of day for each recess movement and calculated average daily distance traveled on recesses during the entire incubation period for each female. I estimated nest attentiveness (Skutch 1962, Collier et al. 2019) by calculating the time the female was on the nest (e.g., within the 27 m buffer). With the low probability of nest success, it could be expected that individuals could be less attentive in order to save energy for future attempts (Martin 1995, Cervencl et al. 2011). Therefore, I then tested for differences between attentiveness, daily frequency, and daily distance traveled for initial and renesting attempts, and successful and unsuccessful nests, using a *t*–test in R (v. 3.2.5, R, Core Development Team 2018).

My nest monitoring data produced a ragged telemetry dataset (Rotella et al. 2004), and I used the nest survival approach outlined by (Dinsmore et al. 2002) to evaluate influences of incubation recess movements on daily nest survival. The ragged telemetry approach serves as a general model for known fate data in program MARK (White and Burnham 1999) when loss date may not be known exactly and is flexible for integrating time-dependent individual covariates (Rotella et al. 2004, Collier et al. 2009). For each nesting female, I created an encounter history for the entire incubation period and scaled each nesting event ($k = 1$) to the same start point, as evaluating temporal variation in nest success was not my objective (Dinsmore et al. 2002). I recorded the last day each nest was known to be alive (l) and the final date that the female incubated (m) based on my VHF and GPS data (Conley et al. 2015, Conley

et al. 2016, Yeldell et al. 2017) and assigned each nest a fate of 0 = survived or 1 = failed. I followed the approach of Collier et al. (2009) and developed time-dependent covariates for both the daily frequency (r) and distance (d) of recess movements, and time-dependent covariates for the cumulative value of daily frequency (rr) and distance (dd) of recess movements. I developed a set of candidate models to evaluate time-specific influences of incubation recesses on nest survival. I included models evaluating time-dependent covariates for both daily frequency of recess movements and daily distance of recess movements (Collier et al. 2009). I also developed trend models for cumulative frequency of recesses and distance of recess movements, which assumed that the effect of each covariate was constant over time. I used an information–theoretic approach (Anderson and Burnham 2002) to rank candidate models and assess model strength, and estimated daily nest survival for the best fitting candidate model given the data.

Incubation recesses facilitate acquisition of resources by incubating females while also ensuring appropriate egg temperatures (Deeming 2002). Wild turkeys are restricted to the region around the nest site for resource acquisition during incubation (Conley et al. 2015), hence, the local landscape must provide sufficient resources (Orians and Wittenberger 1991). As foraging bouts are typically habitat-type specific (Deeming 2002), the availability of specific habitat types could potentially shape incubation behavior. Therefore, I evaluated habitat use by females during the incubation period. I used a dynamic Brownian Bridge movement model (hereafter, DBBMM) to build utilization distributions (UD) at 50% and 99% ranges for each female during incubation (Byrne et al. 2014). I calculated all UDs (Kranstauber et al. 2018) in R (v. 3.2.5, R, Core Development Team 2018) with R package move (Kranstauber and Smolla 2013) using a window and margin size equal to 7 and 3 respectively, and a location error of 20 m (Byrne et al. 2014). I kept window and margin size constant to account for changes in GPS sampling

frequency because I failed to see any measurable effects of altering these values when I began my analysis (Cohen et al. 2018). Using 30 m resolution imagery from USGS Landsat–8 Operational Land Imager, I delineated primary habitat types on my study areas during the month of May for years 2014–2017, excluding images with ≥ 10% cloud cover. I chose imagery from the month of May as that was midpoint of the nesting season and I assumed would capture habitat conditions representative of the nesting period. I used an unsupervised classification in ERDAS Image software (v16.00.0000.00199, Hexagon Geospatial, Peachtree Corners Circle Norcross 2016) with 30 classes and recoded and combined classes to create 6 unique habitat classes (water, coniferous, deciduous, mixed coniferous–deciduous, and infrastructure). Within each UD, I estimated the proportion of each habitat type to provide an assessment of habitat use by incubating females.

2.4. Results

I monitored 396 nesting attempts by 278 (246 adults, 32 juveniles) female wild turkeys during 2014–2017. I observed that 26 females died within 3 weeks of capture, and I censored 23 nesting attempts because of incomplete GPS data resulting from failed transmitters. For the remaining 373 nesting attempts, females incubated nests an average of 10 days (SD = 7; median

= 7, range = 1–29) and 75% of nesting attempts failed by day 14 (Figure 2.2.).

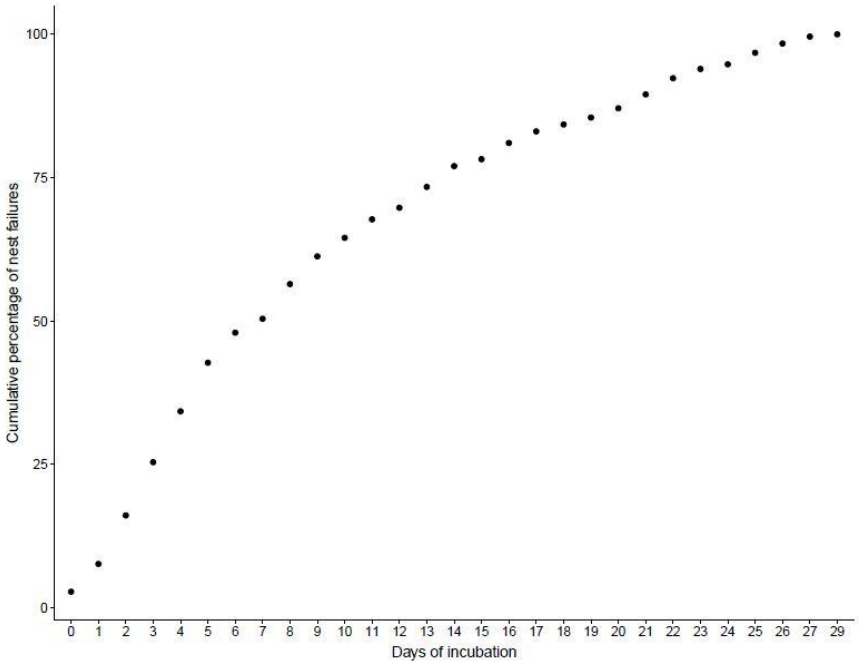

Figure 2.2. Cumulative nest failure by day of incubation for female Eastern wild turkey (*Meleagris gallopavo silvestris*) across multiple study sites in the southeastern United States during 2014–2017.

I removed 58 females who incubated < 4 days due to lack of spatial data needed to accurately estimate UDs for incubating females, and ultimately used 315 nesting attempts (initial attempts = 220, renesting attempts = 95) by 220 females to quantify recess behaviors and habitat use by incubating females (Table 2.1.).

Table 2.1. Numbers of initial nesting attempts, renesting attempts, and fate of 315 nest attempts of female Eastern wild turkeys (*Meleagris gallopavo silvestris*) across multiple study sites in the southeastern United States during 2014–2017.

Study Site	Initial	Renest	Success	Fail
Angelina National Forest	25	12	2	35
B.F Grant Wildlife Management Area	8	5	1	12
Caddo Parish	5	1	2	4
Cedar Creek Wildlife Management Area	24	7	5	26
Kisatchie National Forest	55	34	17	72
Peason Ridge Wildlife Management Area	26	8	2	32
Silver Lake Wildlife Management Area	33	21	24	30
Webb WMA Complex	44	7	24	27
Total	220	95	77	238

I identified 10,329 movements off nests and 7,115 recess events based on approximately 69,409 hours of incubation across all study sites (Table 2.2.).

Table 2.2. Mean number of days of incubation, mean number of GPS locations collected while a female was incubating, mean number of recesses per female during incubation, total hours of recesses, and estimates of nest attentiveness for 220 female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during nesting by site for the years 2014–2017.

Study Site	Mean Days Incubated (SD)	Mean GPS Locations (SD)	Mean Recesses per Individual (SD)	Total Hours of Recesses	Nest Attentiveness (%)
Angelina National Forest	12 (6.4)	179 (119.0)	15 (9.9)	824	87
B.F Grant Wildlife Management Area	9 (8.2)	123 (123.0)	24 (24.1)	513	70
Caddo Parish	21 (9.3)	111 (53.0)	7 (6.1)	196	78
Cedar Creek Wildlife Management Area	15 (8.9)	227 (137.1)	41 (26.3)	1869	73
Kisatchie National Forest	13 (9.0)	198 (144.6)	22 (20.5)	2613	84
Peason Ridge Wildlife Management Area	13 (7.9)	193 (130.0)	17 (17.0)	826	88
Silver Lake Wildlife Management Area	17 (9.3)	262 (160.6)	19 (14.3)	1491	88
Webb WMA Complex	19 (8.5)	296 (144.6)	26 (17.7)	1926	84

I estimated average nest attentiveness of 84.0% (SD = 0.13, range = 0–0.986), and nest attentiveness did not differ by nest fate (t = -1.37, df = 121.87, P = 0.173).

Recess movements occurred between 1000–1500 52% of the time (Figure 2.3.) and mean number of recesses per day was 1.7 (SD = 0.19, median = 1.7, range = 0–8).

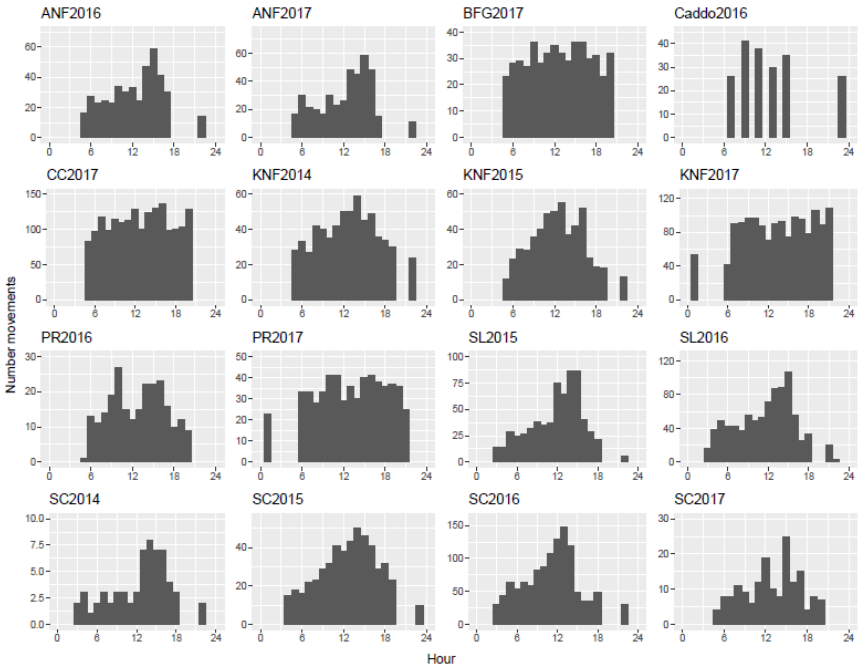

Figure 2.3. Hourly recess movements for female Eastern wild turkey (*Meleagris gallopavo silvestris*) across multiple study sites in the southeastern United States during 2014–2017.

I found that mean number of recesses per day differed between successful (mean = 1.6, SD = 0.22, range = 0–7; Table 2.3.) and unsuccessful (mean = 1.7, SD = 0.19, range = 0–8) nests (t = -2.22, df = 53.90, P = 0.031; Figure 2.4.), but offer that this difference is not biologically relevant.

Table 2.3. Mean number of daily incubation recesses and associated standard deviation for successful and unsuccessful, initial nesting and renesting attempts for female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during 2014–2017.

Study Site	Mean Number Recess (SD)	Number of Recess Range	Mean Recesses Successful Nest (SD)	Mean Recesses Failed Nest (SD)	Mean Recesses Initial Attempt (SD)	Mean Recesses Renest Attempt (SD)
Angelina National Forest	1.5 (0.97)	0 – 4.5	0.38 (0.03)	1.6 (0.96)	1.3 (0.64)	2.0 (1.25)
B.F Grant Wildlife Management Area	2.4 (0.73)	1.3 – 3.8	3	2.7 (0.73)	2.5 (0.56)	2.7 (1.00)
Caddo Parish	0.6 (0.37)	0.08 – 1	0.5 (0.30)	0.6 (0.44)	0.7 (0.38)	0.3
Cedar Creek Wildlife Management Area	2.7 (0.68)	1 – 3.8	2.5 (0.90)	2.4 (0.65)	2.7 (0.71)	2.7 (0.62)
Kisatchie National Forest	1.7 (0.73)	0.3 – 4.0	1.8 (0.93)	1.8 (0.67)	1.7 (0.62)	1.9 (0.87)
Peason Ridge Wildlife Management Area	1.3 (0.68)	0.4 – 3.0	1.6 (0.92)	1.2 (0.68)	1.3 (0.71)	1.1 (0.61)
Silver Lake Wildlife Management Area	1.2 (0.44)	0.5 – 2.5	1.2 (0.52)	1.2 (0.39)	1.3 (0.46)	1.2 (0.43)
Webb WMA Complex	1.5 (0.65)	0.2 – 3.4	1.5 (0.61)	1.5 (0.69)	1.4 (0.68)	1.5 (0.34)

I found no difference in mean number of daily recesses between initial nesting attempts (1.6, SD = 0.26, range = 0–6) and renesting attempts (1.6, SD = 0.36, range = 0–8, t = -0.80, df = 49.02 P = 0.428). Average number of recesses did not differ between successful and unsuccessful nests for first nesting attempts (t = -1.00, df = 54.78, P = 0.321). However, average number of recesses was greater (t = -3.625, df = 51.54, P = 0.001) for failed (1.86, SD = 0.30, range = 1–

2.3.) than successful renests (1.56, SD = 0.33, range = 1.1–3.0).

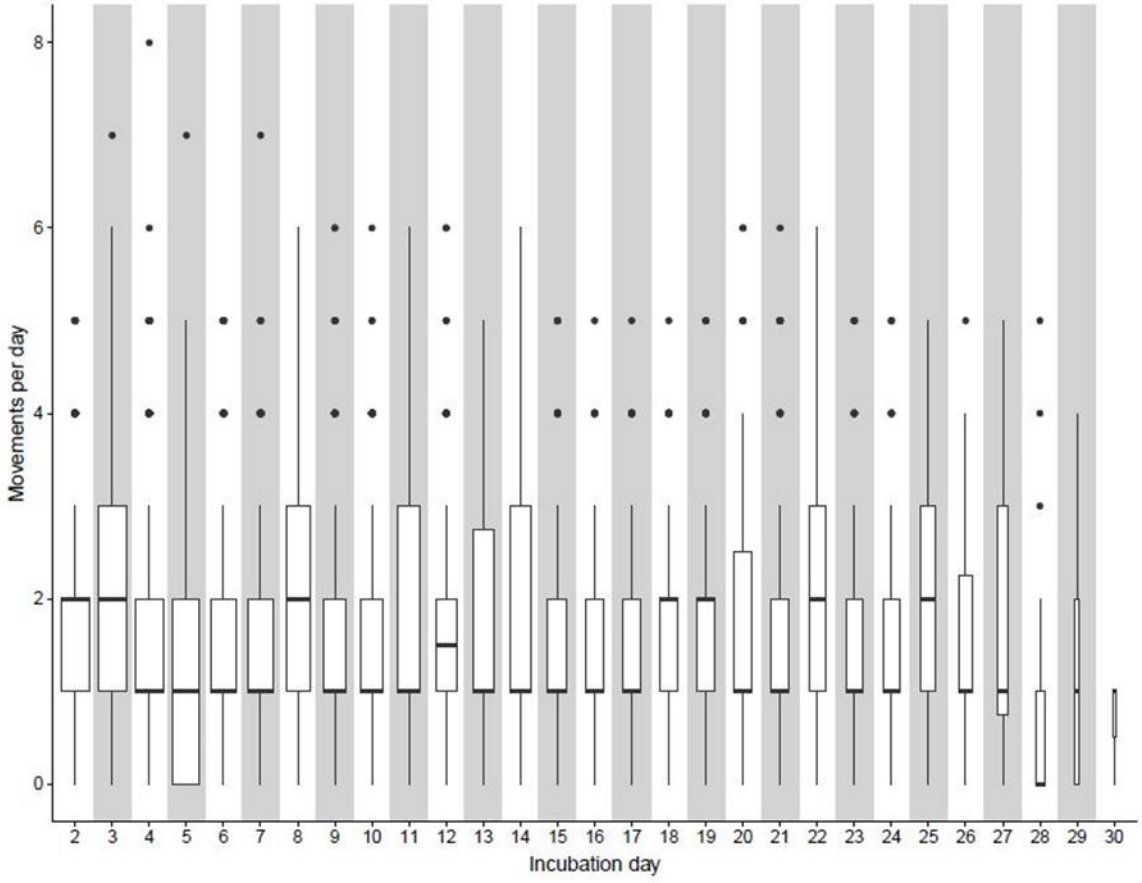

Figure 2.4. Number of recesses made by birds with successful attempts, failed attempts, initial attempts, and renest attempts by incubation days across all study sites for year 2014–2017.

Average daily distance moved during the incubation period was 92.2 m (SD = 22.9, range = 0–998.5 m). Females with failed nesting attempts did not move farther (96.7 m, SD = 27.3, range = 0–780.7 m) than successful females (91.0 m, SD = 25.7, range = 0–998.5 m; t = -0.818, df = 53.95, P = 0.417; Figure 2.5.). Average daily distance moved did not differ between initial (mean = 91.9 m, SD = 39.4, range = 0–259.6 m), and renesting attempts (mean = 90.9 m, SD =

24.8, range = 0–998.5 m) (t = 0.123, df = 47.41, P = 0.903).

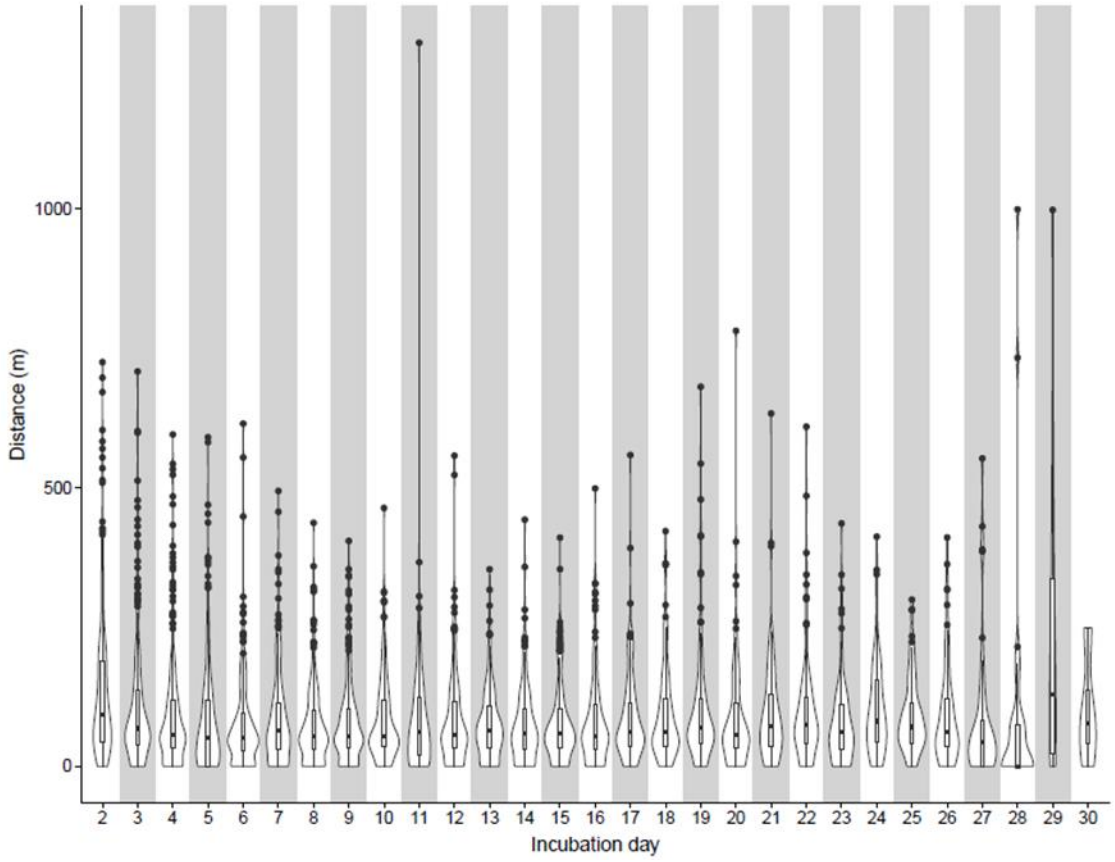

Figure 2.5. Mean recess distance moved by incubation date for successful attempts, failed attempts, initial attempts, and renesting attempts across all study sites for years 2014 – 2017.

I found no difference in average daily distance moved during incubation for first nesting attempts (t = -0.567, df = 47.21, P = 0.574), and whereas average daily distance moved was greater (t = -2.215, df = 48.28, P = 0.034) for renests that failed (106.54 m, SD = 30.4, range = 34.1–179.7 m) than those that were successful (90.3 m, SD = 22.9, range = 54.6–140.6 m), I offer that a difference of 16 m is likely not biologically relevant and within error of the GPS units.

The best model for estimating daily nest survival included time–specific main effects for number of recesses and distances of each recess movement, and included an interaction of these main effects (Table 2.4., Appendix 1).

Table 2.4. Candidate models used to examine the effect of frequency of daily recess movement intensity and distance of daily recess movements on daily nest survival of Eastern wild turkeys in the southeastern United States 2014–2017.

Model notation	k	Deviance	ΔAIC_c	w_i
S (No. recess movements + Recess distance + No. recess movements * Recess distance)[a]	4	1846.00	0	0.867
S (Recess distance)[b]	28	1801.73	1.13	0.131
S (No. recess movements)[b]	28	1805.20	1.64	0.019
S (Cumulative No. Recess movements)[a]	2	1869.55	1.95	<0.001
S (Cumulative Recess distance)[a]	2	1869.75	2.02	<0.001
S (Recess distance)[a]	2	1870.91	2.97	<0.001
S (No. recess movements)[a]	2	1872.52	3.65	<0.001

[a] Effect is constant over time

[b] Effect is time-dependent

However, I note that there was considerable model selection uncertainty within my model set. Based on the best fitting model, I predicted daily nest survival of 0.94, with an expected overall nest survival rate of 0.22 (SE = 0.22, CI = 0.18–0.27) given the average number of recess movements per day (1.7) and average distance per recess (92 m). I generated estimates of predicted daily nest survival across the number of recess movements taken per day by an individual (range 1–6) and found that daily nest survival was constant for individuals that made a single recess movement, but as the number of recess movements per day and mean recess

distance increased, daily nest survival increased (Figure 2.6.).

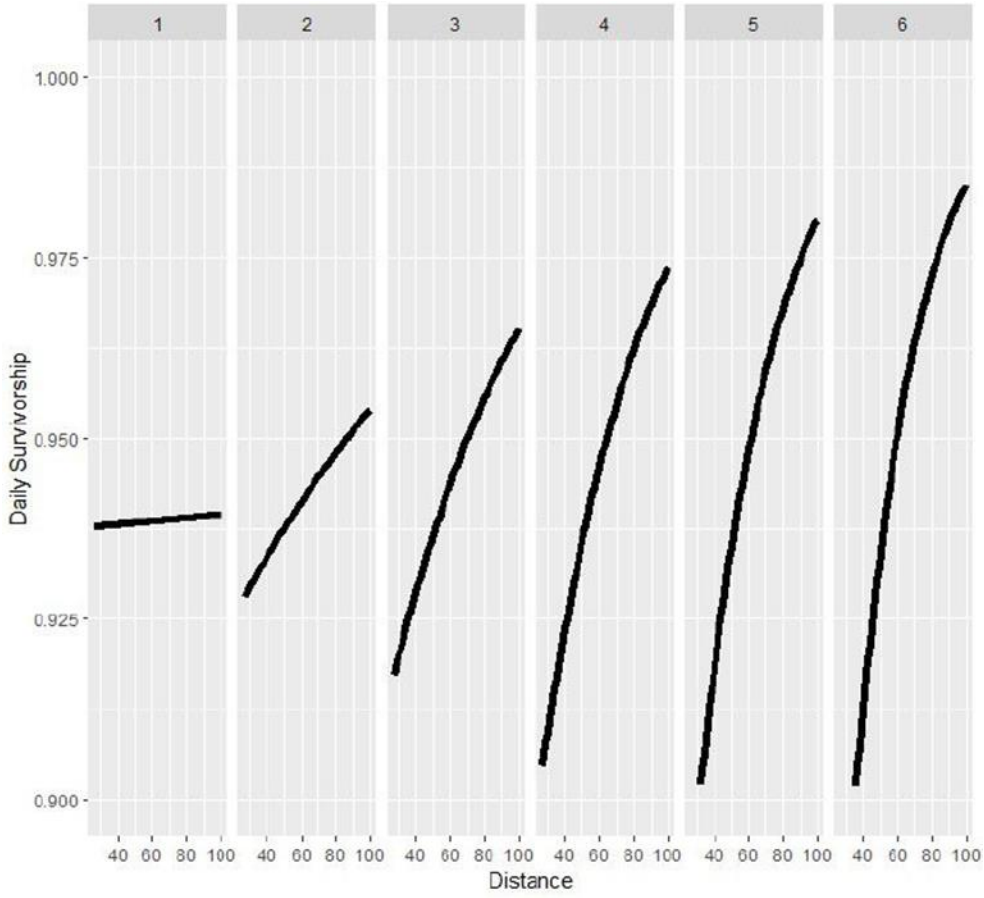

Figure 2.6. Average daily distance travelled during incubation by incubation date for all study sites 2014–2017.

I note that the estimated overall nest survival rate of 0.22 was comparable to a naïve estimate of nest success (24%) from my data.

Mean size of incubation ranges at the 50 % UD was 0.2 ha (SD = 0.4, range = 0.03–6.48 ha), whereas 99% UDs averaged 11.6 ha (SD = 17.6, range = 0.23–111 ha). Pine was the dominant habitat type (57%; SD= 32.5, range = 0–100, Table 2.5.) within incubation ranges across all study sites.

Table 2.5. Mean size of 50% and 99% utilization distributions for incubation recess ranges, and proportion of habitat types within the ranges for female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during 2014–2017.

Site	Mean Incubation Range (ha)	Mean Proportion Pine 99% (SD)	Mean Proportion Hardwoods 99% (SD)	Mean Proportion Mixed 99% (SD)	Mean Proportion Open 99% (SD)	Mean Proportion Infrastructure 99% (SD)	Mean Proportion Water 99% (SD)	Mean Proportion Pine 50% (SD)	Mean Proportion Hardwoods 50% (SD)	Mean Proportion Mixed 50% (SD)	Mean Proportion Open 50% (SD)	Mean Proportion Infrastructure 50% (SD)	Mean Proportion Water 50% (SD)
Angelina National Forest	13.7 (22.4)	18.7 (23.7)	25.6 (19.1)	34.6 (24.0)	10.7 (15.0)	0 (0)	10.4 (16.6)	14.0 (30.8)	20.7 (32.9)	29.1 (34.4)	20.0 (31.3)	0 (0)	8.1 (21.2)
B.F. Grant Wildlife Management Area	27.6 (27.2)	77.3 (18.5)	1.0 (1.9)	11.0 (10.8)	9.8 (11.4)	0 (0)	0.1 (1.5)	82.3 (34.2)	0 (0)	11.4 (27.9)	11.7 (29.7)	0 (0)	0 (0)
Caddo Parish	11.6 (14.3)	27.5 (28.0)	25.4 (37.5)	13.4 (23.5)	31.8 (40.1)	0.1 (0)	1.8 (3.5)	8.8 (14.0)	46.9 (45.8)	13.4 (23.5)	33.0 (43.5)	0 (0)	0 (0)
Cedar Creek Wildlife Management Area	29.2 (28.8)	75.7 (23.7)	1.9 (6.4)	11.9 (16.9)	9.2 (14.1)	0 (0)	1.4 (5.3)	82.9 (32.6)	2.6 (14.3)	3.2 (10.4)	10.6 (24.9)	0 (0)	0.6 (3.7)
Kisatchie National Forest	8.9 (11.7)	74.0 (24.3)	3.3 (7.4)	9.4 (18.2)	7.9 (15.0)	3.5 (7.3)	1.8 (8.3)	75.7 (35.7)	4.2 (16.4)	9.1 (24.0)	7.7 (22.2)	1.7 (8.3)	1.6 (11.1)
Peason Ridge Wildlife Management Area	6.9 (7.7)	54.7 (24.1)	1.8 (3.8)	22.0 (21.1)	12.7 (19.7)	8.5 (16.9)	0 (2.0)	65.1 (39.9)	0 (0)	21.0 (34.0)	14.3 (31.0)	5.8 (16.8)	0 (0)
Silver Lake Wildlife Management Area	5.4 (5.6)	65.8 (26.0)	11.3 (13.5)	3.7 (12.0)	14.9 (22.0)	1.2 (2.5)	3.0 (11.0)	65.0 (42.0)	9.6 (24.0)	3.7 (18.0)	19.8 (36.4)	1.4 (10.2)	0.3 (1.2)
Webb WMA Complex	9.5 (15.2)	33.4 (29.7)	7.9 (10.2)	41.9 (36.3)	5.0 (12.1)	0.6 (1.7)	11.1 (15.0)	33.4 (40.1)	1.8 (6.7)	47.4 (47.2)	3.9 (15.6)	0 (0)	13.4 (29.1)

I found no significant difference between percentage of pine within the 99% UD (t = 0.697, df = 129.48, P = 0.487; Table 2.6.) for successful and failed nests. However, greater percentages of pine within the 50% UD were associated with reduced nest success (t =2.297, df = 122.50, P = 0.023).

Table 2.6. Mean proportion of habitat types within the 50% and 99% ranges for female Eastern wild turkeys (*Meleagris gallopavo silvestris*) based on nest fate (successful or fail), nesting attempt (initial or renest), and age (adult or juvenile) during 2014–2017.

	Mean Proportion Pine 99% (SD)	Mean Proportion Hardwoods 99% (SD)	Mean Proportion Mixed 99% (SD)	Mean Proportion Open 99% (SD)	Mean Proportion Infrastructure 99% (SD)	Mean Proportion Water 99% (SD)	Mean Proportion Pine 50% (SD)	Mean Proportion Hardwoods 50% (SD)	Mean Proportion Mixed 50% (SD)	Mean Proportion Open 50% (SD)	Mean Proportion Infrastructure 50% (SD)	Mean Proportion Water 50% (SD)
Successful	0.50 (0.31)	0.10 (0.16)	0.19 (0.31)	0.10 (0.20)	0.02 (0.08)	0.04 (0.09)	0.50 (0.43)	0.10 (0.28)	0.19 (0.36)	0.14 (0.31)	0.01 (0.09)	0.06 (0.14)
Fail	0.59 (0.33)	0.08 (0.13)	0.18 (0.24)	0.10 (0.18)	0.02 (0.04)	0.04 (0.11)	0.59 (0.43)	0.08 (0.20)	0.17 (0.32)	0.12 (0.27)	0.01 (0.08)	0.03 (0.21)
Initial Attempt	0.56 (0.33)	0.08 (0.13)	0.19 (0.27)	0.10 (0.17)	0.02 (0.08)	0.04 (0.11)	0.57 (0.43)	0.08 (0.22)	0.20 (0.35)	0.10 (0.26)	0.01 (0.06)	0.04 (0.17)
Renest Attempt	0.59 (0.33)	0.09 (0.16)	0.12 (0.24)	0.15 (0.21)	0.02 (0.05)	0.03 (0.11)	0.59 (0.44)	0.09 (0.23)	0.11 (0.28)	0.16 (0.32)	0.02 (0.12)	0.03 (0.12)
Adult	0.58 (0.33)	0.08 (0.19)	0.18 (0.26)	0.10 (0.18)	0.02 (0.07)	0.04 (0.11)	0.59 (0.44)	0.08 (0.23)	0.17 (0.33)	0.12 (0.28)	0.02 (0.09)	0.03 (0.15)
Juvenile	0.51 (0.34)	0.08 (0.16)	0.23 (0.24)	0.11 (0.22)	0.01 (0.04)	0.06 (0.11)	0.46 (0.41)	0.07 (0.19)	0.25 (0.33)	0.13 (0.31)	0 (0)	0.09 (0.25)

2.5. Discussion

My results indicated that the average number of days a female wild turkey incubated a nest was 10 days, and 75% of nesting attempts failed by day 14. Recess movements were distributed throughout the day, with the majority of movements occurring during the middle of the day and early afternoon (1000–1500). My estimates of nest attentiveness suggest that hens spent between 1–2 hours per day recessing away from the nest. My nest attentiveness estimates were lower (84%) relative to other ground nesting galliforms, including greater sage–grouse (96%; *Centrocercus urophasianus*), and white–tailed ptarmigan (95%; *Lagopus leucura*) (Wiebe and Martin 2000, Deeming 2002, Coates and Delehanty 2008).

I found that daily nest survival was influenced by recess behaviors, but the impact of recess behaviors was limited to those individuals who recessed more than once per day. Fitness consequences of recess movements have been found in white–tailed ptarmigan wherein individuals making fewer and shorter recess movements have a decreased probability of nest predation events and hence increased nest survival (Wiebe and Martin 1997) while in greater sage–grouse the amount of time spent away from the nest declined with increased predator abundance, likely driven by the need to reduce interactions with nest predators (Coates and Delehanty 2008). Similarly, shorebird species that made 17% fewer recesses during incubation had a higher chance of nest success (Smith et al. 2012). Conversely, wild turkeys are known to maximize survival relative to reproductive output (Collier et al. 2009), and in systems with increased predation risk, I would expect reduced nest attentiveness and increased recess movements by individuals choosing to maximizing survival over reproduction (Cerencl et al. 2011, Behrens et al. 2019). My results suggest that for wild turkeys reduced nest attentiveness

and increased recess movements may confer positive fitness consequences relative to nest survival. Further research needs to evaluate avian species at an individual level to understand different strategies throughout species.

Nest failure due to predation is likely a random process driven by multi-factor interaction of predator abundance, predator distribution, and turkey nest distribution on the landscape. Predation risk can alter individual behaviors/time allocation patterns (Laundré et al. 2010) and as such the intensity of nest predation over time likely underlies plasticity in behavioral responses or antipredator strategies (Conway and Martin 2000, Ghalambor and Martin 2000, Martin 2002). My results show that frequency of recesses, distance traveled during recess movements, and available resources did not differ between successful and failed nests. Conversely, females that renested and took more recesses had reduced success, which suggests that remaining on the nest as the nesting season progresses may be a more optimal strategy.

My collective understanding of recess behavior in wild turkeys is based on limited literature (Williams et al. 1971, Green 1982). My approach to assessing recess behavior was the first to describe a standard, repeatable approach for identifying recess frequency and movements. I found throughout the incubation period birds varied in number of recess movements from 0–8 a day compared to previous works suggesting individuals leaving once every two days (Williams et al. 1971). Taken in combination, our results suggest that wild turkeys leave the nest more frequently than others research studies have found. My work between links fitness outcomes to the daily behavioral activities of wild turkeys.

CHAPTER 3. FRAMING A CONCEPTUAL MODEL FOR EASTERN WILD TURKEY REPRODUCTIVE ECOLOGY.

3.1. Introduction

Informed management of natural resources requires that decision processes use available information combined with expert knowledge describing the biological processes expected to underlie population dynamics (Clark et al. 2001). Conceptualizing model structures for population dynamics research is difficult because no single characteristic adequately describes any system (Lebreton and Clobert 1991, Carpenter 1996, Munns Jr 2006). Models for population dynamics typically hinge on our ability to identify causal links between demographic and environmental processes, such that models adequately represent the biological drivers and the quality of biological data that can be collected to support management decisions (Kinzig 2001, White and Lubow 2002, Roux et al. 2006). However, researchers regularly develop interests in certain niches and lose sight of broader ecological systems (Norton 1998).

Population predictions models are typically simulations (Crouse et al. 1987, McDonald and Caswell 1992, Lacy and Clark 1993, Fahrig and Merriam 1994, Caswell 2006, Clark and Martin 2007) that are caricatures of the suite of measureable and unmeasurable biological process that underlie system dynamics. Simulation models are used to make predictions about population trajectories as demographics change in relation to survival, reproduction, and harvest rates (Ricker 1975, Crouse et al. 1987, Burger Jr et al. 1994, Caswell 2006). However, simulation models regularly aggregate individuality and assume that complex ecological processes can be described as a single variable, violating biological principles of most systems (Huston et al. 1988, Judson 1994). Alternatives, such as individual–based or agent models, have been used to incorporate ecological processes and provide a more biologically relevant view of

population dynamics (Huston et al. 1988, Judson 1994, Letcher et al. 1998, DeAngelis 2018). However, these models often do not address the broad range of uncertainty that biological parameters encompass (Minor et al. 2008). Furthermore, evaluating sensitivity of simulation models hinges on strict assumptions that all parameters are held constant except the parameter of interest, which is rarely biologically appropriate (Gardner et al. 1981, Draper 1995). As simulation models are limited in their ability to encapsulate the range of variation in a suite of interacting input parameters, multiple authors (Crouse et al. 1987, Huston et al. 1988, Harley et al. 2001, Gove et al. 2002, Schaub and Abadi 2011) have approached information integration using different methods that better embrace uncertainty in ecological systems.

A variety of approaches for integrating information from a plethora of sources into population modeling frameworks exist (Fryxell et al. 1988, Laake 1992, Besbeas et al. 2002, Besbeas et al. 2005, Skalski et al. 2007, Schaub and Abadi 2011, Ahrestani et al. 2017). For example, integrated population models allow use of data from multiple unconnected studies to be integrated into a predictive framework (Harley et al. 2001, Besbeas et al. 2002, Gove et al. 2002, Besbeas et al. 2005, Schaub and Abadi 2011). Although multiple data sources increases robustness and deals with missing or unequal temporal data coverage in datasets (Schaub and Abadi 2011), similar approaches require strict assumptions that limit biological realism. Therefore, models that more adequately represent causality within the system give researchers the opportunity to evaluate simultaneous interactions while accounting for uncertainty in parameters (Borsuk et al. 2004).

Throughout the history of wild turkey (*Meleagris gallopavo*) research, population models have been developed to predict the potential impact of demographic change on population trajectories (Porter et al. 1990, Roberts et al. 1995, Rolley et al. 1998, Alpizar-Jara et al. 2001,

Norman et al. 2001, Pollentier et al. 2014a, Pollentier et al. 2014b). These models have typically been structured as simulations (Porter et al. 1990, Roberts et al. 1995, Pollentier et al. 2014a, Pollentier et al. 2014b), with input parameters typically chosen from a subset of literature or from field studies and aggregated across individuals, with fairly strict mathematical assumptions regarding the structure of the relationship between covariates and predictions. In an effort to better incorporate information into a biologically relevant framework, I used a Bayesian belief network (BBN) to frame a conceptual model for wild turkey reproductive fate.

Graphical models such as BBN, are built using an underlying framework that represents identified biological relationships (Charniak 1991, Marcot et al. 2001, Borsuk et al. 2004, McNay et al. 2006, MacPherson et al. 2018) via explicit definition of conditional probabilities between causal links. Using a BBN allows researchers to incorporate and evaluate a range of uncertainty in input parameters, and determine relative importance of individual and causally linked variables on network predictions, all while incorporating uncertainty from multiple inputs (Marcot et al. 2001). Because biological models best serve resource managers when integrating as much system information into a realistic framework as possible, we used a BBN to encapsulate data on spatial and temporal behavioral processes used by nesting wild turkeys, and information on local and scaled vegetative characteristics, to provide a detailed accounting of variable relevance to nest success while fully incorporating system uncertainty.

3.2. Study area

I conducted my research on 7 different study sites (Figure 3.1.). In South Carolina, I conducted my work on the Webb WMA Complex, which is comprised of 3 contiguous Wildlife Management Areas (WMAs; Webb, Palachacola, and Hamilton Ridge) owned and managed by the South Carolina Department of Natural Resources (Wightman et al. 2018). Located in

Hampton and Jasper counties, the Webb WMA Complex was 10,483 ha and consisted of mostly bottomland hardwoods typical of the Savannah River and upland hardwood stands along drainages (4,673 ha) whereas approximately 3,346 ha was comprised of planted and managed upland pines. The remaining 2,464 ha were comprised of mixed-pine hardwoods, wildlife openings, and wetlands.

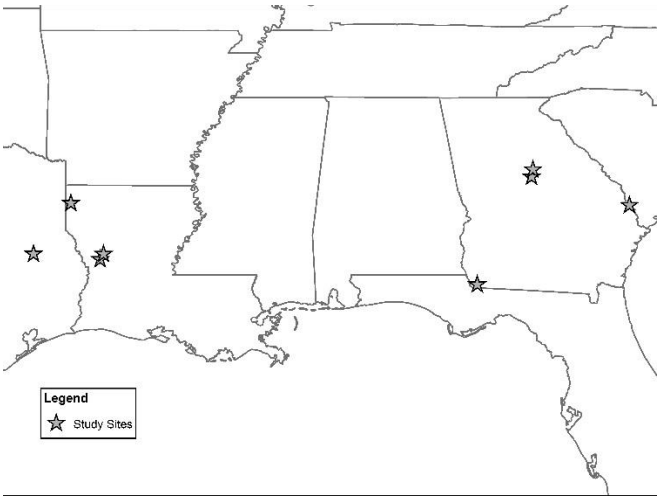

Figure 3.1. Map of study sites across the southeastern United States where research was conducted on female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during 2014–2017.

In Georgia, I conducted research on B.F. Grant and Cedar Creek WMAs, located in central Georgia. Wildlife management activities on both properties were overseen by the Georgia Department of Natural Resources Wildlife Resources Division (GADNR) through cooperative agreements for hunting, fishing, and outdoor recreation (Gulsby et al. 2015). B.F. Grant WMA was approximately 4,610 ha, consisting of managed loblolly pine (*Pinus taeda*) plantation and was used as an agricultural research station by the University of Georgia who maintained pastures consisting of fescue (*Schedonorus arundinaceus*) and Bermuda grass (*Cynodon dactylon*). The Cedar Creek WMA was approximately 16,190 ha that consisted of mature

loblolly pine with closed-canopy forest. Timber management on Cedar Creek WMA consisted primarily of salvage operations conducted by the United State Forest Service (USFS).

My second Georgia site was the Silver Lake Wildlife Management Area (Silver Lake WMA) in southwestern Georgia. Silver Lake WMA was a 3,900 ha state owned property in Decatur County. Approximately 88% of Silver Lake WMA was pine with approximately 83% considered mature pine at ≥ 20 years old, and 14% pine plantation between 4–19 years old (Wood et al. 2018). Dominant overstory species included longleaf (*Pinus palustris*) and, to a lesser extent, loblolly pine, slash pine (*Pinus elliottii*), shortleaf pine (*Pinus echinata*), oaks (*Quercus* spp.), and sweet gum (*Liquidambar styraciflua*). Understory vegetation was dominated by wiregrass (*Aristida stricta*), broomsedge (*Andropogon* spp.), bracken fern (*Pteridium* spp.), runner oak (*Quercus pumilla*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), muscadine (*Vitis rotundifolia*), American beautyberry (*Callicarpa americana*), common ragweed (*Ambrosia artemisiifolia*), and greenbrier (*Smilax* spp.).

In Louisiana, I conducted research on the Kisatchie National Forest (KNF) and Peason Ridge WMA in west central Louisiana, and on private lands in western Caddo Parish. The KNF was owned and managed by the USFS and our work was in the Kisatchie, Winn, and Calcasieu Districts, located in Natchitoches, Winn, and Vernon parishes. Peason Ridge and Fort Polk WMA were jointly owned by the USFS and the United States Department of Defense. The spatial extents of Kisatchie Ranger District, Winn Ranger District, the Vernon-Fort Polk, Peason Ridge WMA area were approximately 41,453 ha, 67,408 ha, 61,202 ha, and 74,309 ha respectively. The area was composed of pine-dominated forests consisting of loblolly pine, longleaf pine, shortleaf pine, slash pine, hardwood riparian zones, and forested wetlands, with forest openings, utility right-of-ways, and forest roads distributed throughout (Yeldell et al.

2017b). Privately owned land surrounding KNF consisted of loblolly pine and clear cuts with limited understory management typically under industrial timber production. My sites in western Caddo Parish were north of Greenwood, Louisiana, and were mostly industrial forests consisting of loblolly pine and clear cuts with limited understory management. Understory consisted of dense vegetation comprised of sweetgum, yaupon (*Ilex vomitoria*), American beautyberry, blackberry, and greenbrier. Rural settlements, agricultural fields, pastures, and hardwood-dominated forested wetlands comprised additional privately owned lands on both our study areas.

In Texas, I conducted work on the Angelina National Forest (ANF) which comprised of 62,423 ha in San Augustine, Angelina, Jasper and, Nacogdoches counties. The ANF was owned and managed by the United States Forest Service (USFS) and was pine dominated with hardwood riparian zones. Overstory stands on the ANF included loblolly pine, shortleaf pine, longleaf pine, sweetgum, and oaks. Understory plant communities were composed of yaupon, American beautyberry, blackberry, and greenbrier (J. Hardin, Texas Parks and Wildlife, unpublished data).

3.3. Methods

I captured turkeys using rocket nets baited with cracked corn during January–March 2014-2017. I identified sex and determined age of captured individuals based on presence of barring on the ninth and tenth primaries (Pelham and Dickson 1992). All individuals were given a numbered, riveted aluminum tarsal band and radio-tagged with a backpack–style GPS–VHF transmitter (Guthrie et al. 2011) produced by Biotrack Ltd. (Wareham, Dorset, UK). I programmed transmitters to take 1 location nightly (23:58:58), and hourly locations between 0500 and 2000 until the battery died or the unit was recovered (Cohen et al. 2018). I released

turkeys at the capture location immediately following processing and any individual who died within 3 weeks of release was considered a post-release mortality and was removed from subsequent analysis.

In 2016, wild turkeys were captured in Louisiana and translocated to Caddo Parish. Upon capture, each individual was given a numbered, riveted aluminum tarsal band and radio–tagged with a backpack–style GPS-VHF transmitter. I programmed the units to record 3 locations daily (0800, 1600, 2400 local time). Turkeys were placed in separate transport boxes, driven to the release sites, and immediately released within 1 to 3 hours of capture (Cohen et al. 2015). Furthermore, during 2016 wild turkeys were captured in Iowa and West Virginia and translocated to ANF, whereas in 2017, wild turkeys were captured in Iowa and Missouri and translocated to ANF. I programmed GPS transmitters on birds translocated to ANF to collect hourly locations (0700 to 1800), along with a roost location at 0000.

I monitored live-dead status daily during the reproductive season using handheld Yagi antennas and R4000 (Advanced Telemetry Systems, Inc., Isanti, MN) or Biotracker receivers (Biotrack Ltd., Wareham, Dorset, UK). I downloaded GPS locations ≥ 1 per week via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). I viewed GPS locations and determined incubation when female locations became concentrated around a single point for several days (Collier and Chamberlain 2011, Conley et al. 2015, Yeldell et al. 2017, Wood et al. 2018). Nesting females were not disturbed or flushed from nest sites during monitoring, but instead were live-dead checked daily via VHF from a distance of > 20 m. All turkey capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee at the University of Georgia (Protocol No. A2014 06-008-Y1-A0 and A3437-01) and the Louisiana State University Agricultural Center (Protocol No. A2015-07).

Following Yeldell et al. (2017), after nest termination I located nest sites to determine nest fate and confirm the precise nest location for future analyses. Wild turkeys require approximately 27 days of continuous incubation to complete nesting (Williams et al. 1971), but incubation can vary from 25 to 29 days (Healy and Nenno 1985). Therefore, I considered a nest to have been depredated or abandoned if the female left the nest ≤ 25 days into incubation, or if only intact eggs, no eggs, or egg fragments were found at the nest bowl.

After nest termination, I evaluated vegetation characteristics at nest sites by conducting vegetation surveys within a 15 m radius circular plot based on the methodologies of Yeldell et al (2017) to facilitate comparisons. I recorded tree density, percent canopy cover, percent ground cover, and visual obstruction (cm). I measured tree density by counting all trees ≥ 10.16 cm diameter breast height (DBH) within 15 m of the nest bowl. I measured percent canopy cover using a convex spherical densiometer (Lemmon 1956) held 1 m from the ground, such that vegetation within any strata above 1 m contributed to readings. I chose 1 m to best approximate the height of a wild turkey (Pelhamand Dickson 1992). I measured canopy cover above the nest bowl and at a distance of 15 m in each of the cardinal directions using a densiometer, then calculated a mean of the 5 readings. I also measured percent ground cover by placing a 1 m 2 quadrat frame on the ground and viewing the quadrat from directly overhead. I recorded percent ground cover as the percentage of ground within the quadrat that was visually obstructed by vegetation. I recorded percent ground cover at the center of the nest bowl and 15 m each cardinal direction, and used the mean value from all 5 frames. To evaluate height of understory vegetation and quantify visual obstruction, I used a 2 m Robel pole (Robel et al. 1970). I placed the Robel pole in the nest bowl and took readings from 15 m in each cardinal direction. I measured visual obstruction as the lowest point of the Robel pole I could see when viewing from

a height of 1 m above the ground at a point 15 m from the nest in each cardinal direction. I averaged Robel pole readings from all 4 readings to estimate mean visual obstruction.

Females will frequently roost away from the nest site the night before initiating incubation (Conley et al. 2016), so I censored data from the first day that incubation was confirmed therefore excluding movements potentially associated with laying of the last egg in the clutch. Additionally, I censored the day of hatch and the previous day of incubation for successful nests to ensure that movements potentially related to newly hatched broods would not influence inferences related to recess behaviors.

There is no published protocol for quantifying what constitutes an incubation recess by wild turkeys. Previous work by Williams et al. (1971) has been widely cited, but inferences from Williams et al. (1971) were based on 10 recess events with an average of 1.5 hours per recess. Furthermore, incubating females were irregularly monitored during the incubation period, and data were interpolated graphically for some of recesses described by Williams et al. (1971). Hence, I sought to develop a rigorous, standardized method to identify recess movements using spatial data. First, based on previous GPS error evaluations (Guthrie et al. 2011), I buffered each nest site by 27 m as per Collier et al. (2019). I then classified any locations > 27 m away from the known nest location as a recess movement, and considered all locations not at the nest but < 27 m from the nest as incubation and not recess movements. I defined a single recess movement as an individual leaving and then returning to the nest at a later time (e.g., $\geq$ 1 location outside of the 27 m buffer). I measured both daily frequency of recess movements and distance and time of day for each recess movement and calculated average daily distance traveled on recesses during the entire incubation period for each female. I estimated nest attentiveness (Skutch 1962, Collier et al. 2019) by calculating the time the female was on

the nest (e.g., within the 27 m buffer). With the low probability of nest success, it could be expected that individuals could be less attentive in order to save energy for future attempts (Martin 1995, Cervencl et al. 2011).

Incubation recesses facilitate acquisition of resources by incubating females while also ensuring appropriate egg temperatures (Deeming 2002). Wild turkeys are restricted to the region around the nest site for resource acquisition during incubation (Conley et al. 2015), hence the local landscape must provide sufficient resources (Orians and Wittenberger 1991). As foraging bouts are typically habitat-type specific (Deeming 2002), the availability of specific habitat types could potentially shape incubation behavior. Therefore, I evaluated habitat use by females during the incubation period. I used a dynamic Brownian Bridge movement model (hereafter, DBBMM) to build utilization distributions (UD) at 50% and 99% ranges for each female during incubation (Byrne et al. 2014). I calculated all UDs (Kranstauber et al. 2018) in R (v. 3.2.5, R, Core Development Team 2018) with R package move (Kranstauber and Smolla 2013) using a window and margin size equal to 7 and 3 respectively, and a location error of 20 m (Byrne et al. 2014). I kept window and margin size constant to account for changes in GPS sampling frequency because I failed to see any measurable effects of altering these values when I began my analysis (Cohen et al. 2018). Using 30 m resolution imagery from USGS Landsat-8 Operational Land Imager, I delineated primary habitat types on my study areas during the month of May for years 2014–2017, excluding images with ≥ 10% cloud cover. I chose imagery from the month of May as that was midpoint of the nesting season and I assumed would capture habitat conditions representative of the nesting period. I used an unsupervised classification in ERDAS Image software (v16.00.0000.00199, Hexagon Geospatial, Peachtree Corners Circle Norcross 2016) with 30 classes and recoded and combined classes to create 6 unique habitat

classes (water, coniferous, deciduous, mixed coniferous–deciduous, and infrastructure). Within each UD, I estimated the proportion of each habitat type to provide an assessment of habitat use by incubating females.

I developed a conceptual reproductive model using key behavioral and environmental variables that have been identified as potentially influencing wild turkey nest site suitability, selection, and movement processes during the incubation period. To identify these variables, I reviewed current literature and gathered expert opinion.

3.3.1. Literature reporting effects of vegetative communities, landscape level characteristics, and behavioral activities on nest fate of Eastern wild turkey (*Meleagris gallopavo silvestris*)

Vegetative Characteristics

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Behavioral Activities

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I used identified variables to construct a draft diagram following proposed structures by Marcot et al. (2006). The diagram consisted of (a) vegetation variables collected at the nest site (canopy cover, ground cover, trees per hectare, visual obstruction), (b) habitat classification proportions which were developed using ERDAS Image software, and (c) behavioral decisions individuals make during the incubation period.

To evaluate factors that influenced nest fate, I constructed a causal model that formed biologically relevant linkages between factors previously shown in the literature to affect nest fate.

Table 3.1. Sample sizes and descriptions of each node used to update the Bayesian Belief Network to evaluate nest fate.

Case file input	Sample size (n)	Description
Visual obstruction	373	Average vegetative height at the nest location
Ground cover	373	Average amount of ground cover at nest location
Trees per hectare	251	Number of trees per hectare at nest location
Canopy cover	373	Perecentage of canopy closure at the nest location
Mixed pine-hardwood	315	Proportion of mixed stand type within the incubation range
Pine	315	Proportion of pine stand type within the incubation range
Hardwood	315	Proportion of hardwood stand type within the incubation range
Open	315	Proportion of open areas within the incubation range
Infrastructure	315	Proportion of infrastructure within the incubation range
Water	315	Proportion of water within the incubation range
Nest fate	396	Identifies nest was successful or fail
Nest attempt	396	Number of nesting attempts and individual made
Days since 12 March laying	396	Number of days from March 12 when an individual laid the first egg
Days since 12 March incubation	396	Number of days from March 12 when an individual began to incubate the nest
Age	396	Identified whether an individual was a juvenile or adult
Incubation range	315	The utilization distribution created using the birds points while incubating the nest in hectares
Average recess distance	315	Average distance in meters an individual travelled daily during an incubation recess
Average number of recesses	315	Average number of recesses an individual made daily away from the nest
Nest Attentiveness	315	Proportion of time an individual remained on the nest during the incubation period

Numerous studies have attempted to link nest success to vegetation characteristics at the nest site (Byrne and Chamberlain 2013, Conley et al. 2015, Streich et al. 2015, Yeldell et al. 2017a, Wood et al. 2018). Therefore, I assumed a direct causal relationship from vegetation characteristics to nest fate. However, vegetative characteristics have also been found to influence behavioral decisions during incubation (Deeming et al. 2002). For instance increased

concealment may reduce visual cues to predators and increase the amount of time an individual can remain on the nest (Yeldell et al. 2017a), or increased vegetation height and ground cover can form favorable microclimates which allow individuals to make more recesses away from the nest (With and Webb 1993). Additionally, vegetation characteristics may influence nest attentiveness (Deeming 2002, Smith et al. 2007, Coates and Delehanty 2008), so, my model had direct causal relationships from vegetation characteristics on nest attentiveness, average number of recess movements, and average recess distance, each of which influenced nest success.

Habitat suitability models using landscape–level attributes have been associated with nest site selection (Glennon and Porter 1999, Thogmartin 1999). Landscape–level attributes have been poor predictors of nest success, hence, I did not link landscape condition directly to nest fate (Miller et al. 1999, Thogmartin 1999, Byrne and Chamberlain 2013). However, wild turkeys are likely to make regular movements during incubation around the nesting location to obtain resources (Conley et al. 2015). Thus, I used a direct causal relationship from average number of recess movements and landscape attributes to the incubation range. Furthermore, I created a direct edge between landscape features and average number of recess movements due to the fact some incubation ranges could supply more or less foraging opportunities (Smith et al. 2007).

Behavioral decisions made during incubation can directly impact nest success (Deeming and Reynolds 2015). Incubation behavior has been described throughout wild turkey research (Williams et al. 1971, Green 1982, Conley et al. 2015), but links between incubation behaviors and there demography are lacking. Recess movements by red phalaropes (*Phalaropus fulicarius*) and little stints (*Calidris minuta*) were shown to negatively impact nest success (Smith et al. 2012). Likewise, of nest attentiveness have found that increases in attentiveness cause positive impacts on nest success, and shorter and fewer recess movements directly affect nest

attentiveness (Wiebe and Martin 1997). Therefore, I assumed a direct linkage from nest attentiveness, average number of recesses, average recess distance, and incubation range to nest fate within my model.

In contrast to most wildlife modeling approaches, BBN use probabilistic expressions describing the relationships between variables (Borsuk et al. 2004). Belief vector structure is based on user-defined bin-widths which then create belief histograms (Fig. 3.2.).

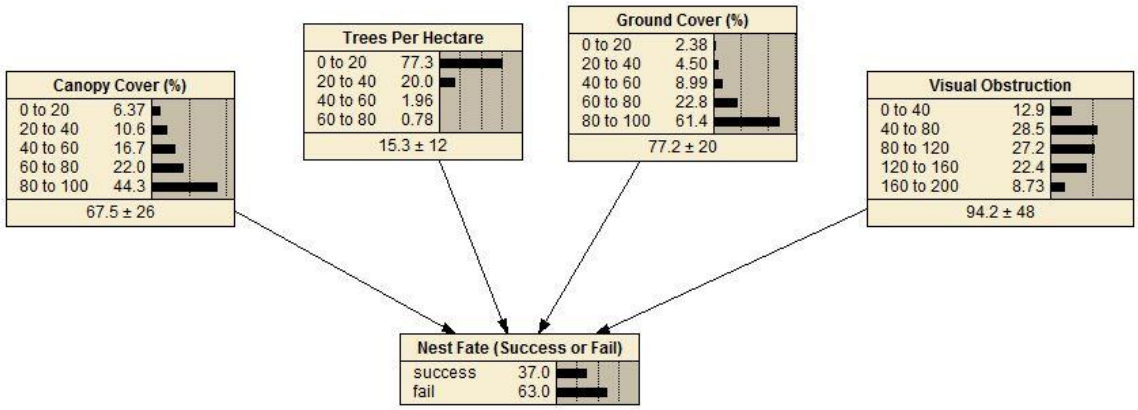

Figure 3.2. Initialized model conditions of vegetation characteristics and how they influence nest fate for female Eastern wild turkeys (*Meleagris gallopavo silvestris*) during 2014-2017.

In our model, bin widths, or the range of the axis covered by each bar within the graphical structure, generally referred to a specified range that a vegetation measurement or behavioral characteristic could take. Because the "true" state of a variable is rarely known, uncertainty is indicated by assigning belief to each range of values within a node (Lee and Rieman 1997). As belief can never be > 1 (e.g. 100%), we used the allocation of belief within each node given the defined bin-width sizes to show the certainty (or uncertainty) associated with the state. A simplified way of understanding BBN is to think of a biological system where causality plays a

role, but my understanding of the mechanisms linking biological factors is incomplete (Charniak 1991). Thus, the purpose of a probabilistic graphical model is to provide the researcher with a repeatable, quantitatively rigorous means to evaluate population responses given this causality, and known or unknown levels of input uncertainty.

I parameterized my conceptual structure to develop a predictive model for nest fate using NeticaTM software (Norsys Software Corporation, 1998) following Marcot et al. (2006). The causal linkages (arrows) defined the conditional probabilistic relationships which underlie the graphical structure. For each node, there exists a conditional probability table that probabilistically describes the relationships between node values. I defined input nodes as those nodes specifying a prior (unconditional) probability, or the likelihood that a parameter was in a specific state. Conditional probabilities for each non-root node represented the likelihood that the parameter was in a specific state, conditional on the state of the input nodes (Marcot et al. 2001). In the models initialized state (Fig. 3.2. in example), the histograms for each node represent the marginal probabilities (belief vectors) for that node.

I conducted sensitivity analysis to examine the influence of parameters on nest fate and on non-direct linkages to nest fate. I conducted sensitivity analysis on graphical model nodes within NETICA. We expressed sensitivity as the percent reduction in variance of the query variable (response variable of interest) given the specification (values) in the findings variables (variables conditionally related to the query variable; B. Boerlage, Norsys Software Corp., personal communication). Because my interest was in evaluating the sensitivity of nest fate to different biological parameters, all sensitivity analysis was conducted in the model's initialized state.

3.4. Results

I used data from 396 nesting attempts by 278 (adults = 246, juveniles 32) female wild turkeys during 2014-2017. I censored 23 nesting attempts because of incomplete GPS data resulting from failed transmitters. For the remaining 373 nesting attempts, I was able to use vegetation metrics measured at the nesting location. I removed 58 females who incubated < 4 days due to the lack of spatial data to accurately estimate incubation range, and conducted recess behavior analyses on 315 nesting attempts (initial attempts = 220, renesting attempts = 95) by 220 females (Table 3.2).

Based on model structure (Figure 3.3.), the probability of findings for nest fate in the initialized state for all input nodes was 37.4% (success) and 62.6% (fail; Table 3.2.).

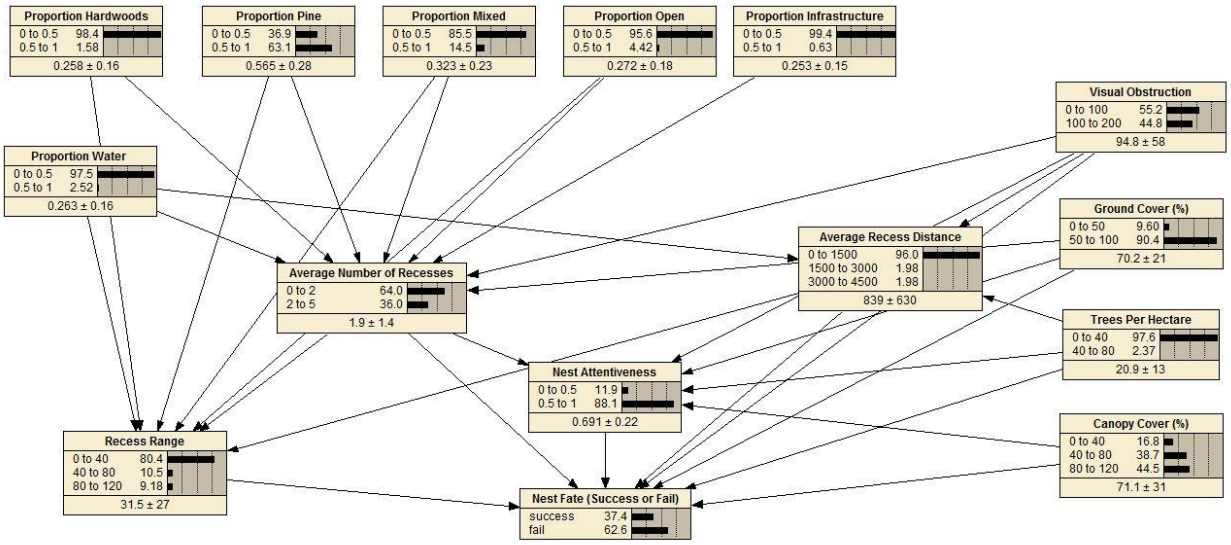

Figure 3.3. Casual framework used to evaluate multiple variables and how they influenced nest fate.

Table 3.2. Means and standard deviations (SD) for node belief histograms that influence (directly and indirectly) nest success.

Node	**Mean (SD)**
Incubation Range	31.5 (27)
Nest Attentiveness (%)	69 (22)
Ground Cover (%)	70.2 (21.0)
Average Recess Distance	839 (630.0)
Canopy Cover (%)	71.1 (31.0)
Trees Per Hectare	20.9 (13.0)
Visual Obstruction	94.8 (58.0)
Proportion Pine (%)	57 (28)
Proportion Water (%)	26 (16)
Proportion Mixed (%)	32 (23)
Proportion Hardwoods (%)	26 (16)
Proportion Open (%)	27 (18)
Average Number of Recess	1.90 (1.40)
Proportion Infrastructure (%)	25 (15)

Nest fate in the natural model state was most sensitive to the node for incubation range, followed by the nodes for nest attentiveness and percentage of ground cover at the nest site (Table 3.3.).

Table 3.3. Sensitivity analysis for node parameters of nest fate based on the initialized model.

Node	Mutual Information	Percent	Variance of Beliefs
Incubation Range	0.01177	1.23	0.0039114
Ground Cover	0.00583	0.612	0.0019512
Nest Attentiveness	0.00524	0.549	0.0017448
Canopy Cover	0.00207	0.218	0.0006734
Average Recess Distance	0.00197	0.206	0.0006585
Trees Per Hectare	0.00149	0.156	0.000501
Proportion Mixed	0.00132	0.138	0.0004334
Proportion Water	0.00065	0.068	0.0002157
Proportion Open	0.00042	0.0442	0.0001392
Proportion Hardwoods	0.00022	0.023	0.0000728
Proportion Pine	0.00008	0.00789	0.0000244
Visual Obstruction	0.00004	0.00429	0.0000133
Average Number of Recess	0.00002	0.00209	0.0000065
Proportion Infrastructure	0.00000	0	0.0000000

My causal model predicted that nest success would be positively influenced by larger incubation ranges (80–120 ha) with a positive percent change of 16.6% from smaller incubation ranges (0–40 ha; Figures 3.4. & 3.5.), lower nest attentiveness (0.0–0.5) with a positive percent change of 13% from higher nest attentiveness (0.5–1.0; Figures 3.6. & 3.7.), and lower levels of ground cover (0–50%) with a positive percent change of 15.0% from higher levels of ground cover (50–

100%; Figures 3.8. & 3.9.).

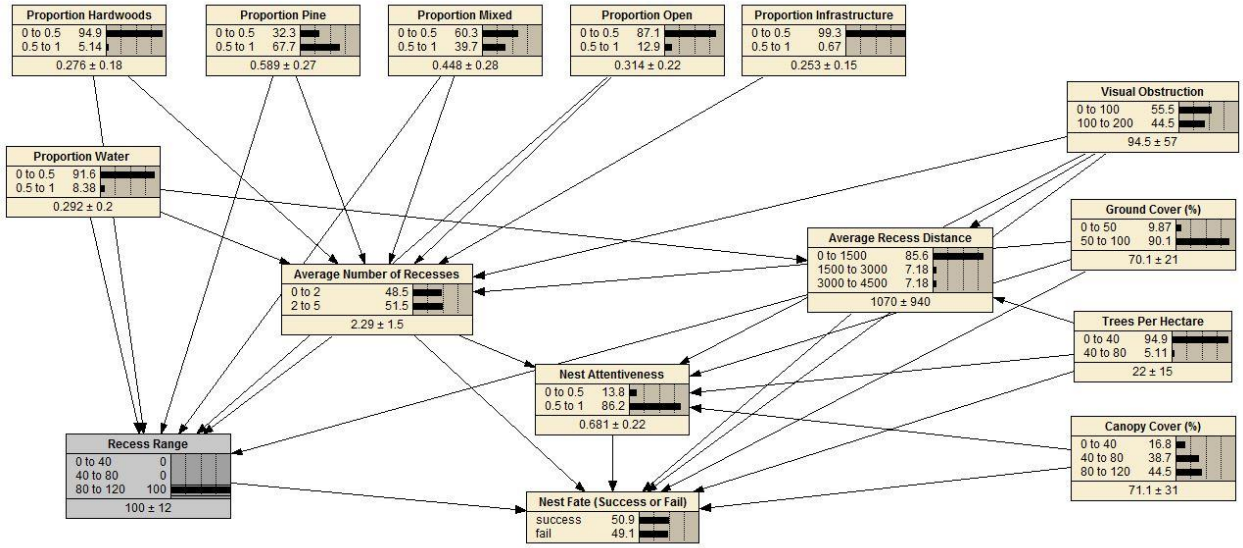

Figure 3.4. Influence of larger incubation range on the casual web and how it positively influenced nest fate.

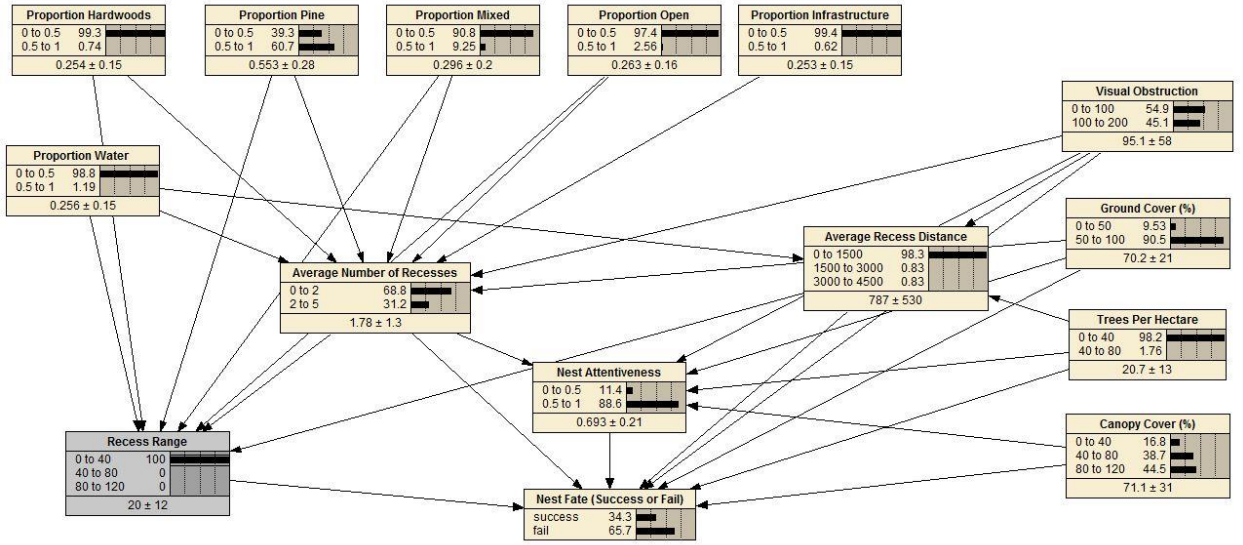

Figure 3.5. Influence of smaller incubation range on the causal web and it negatively influenced nest fate.

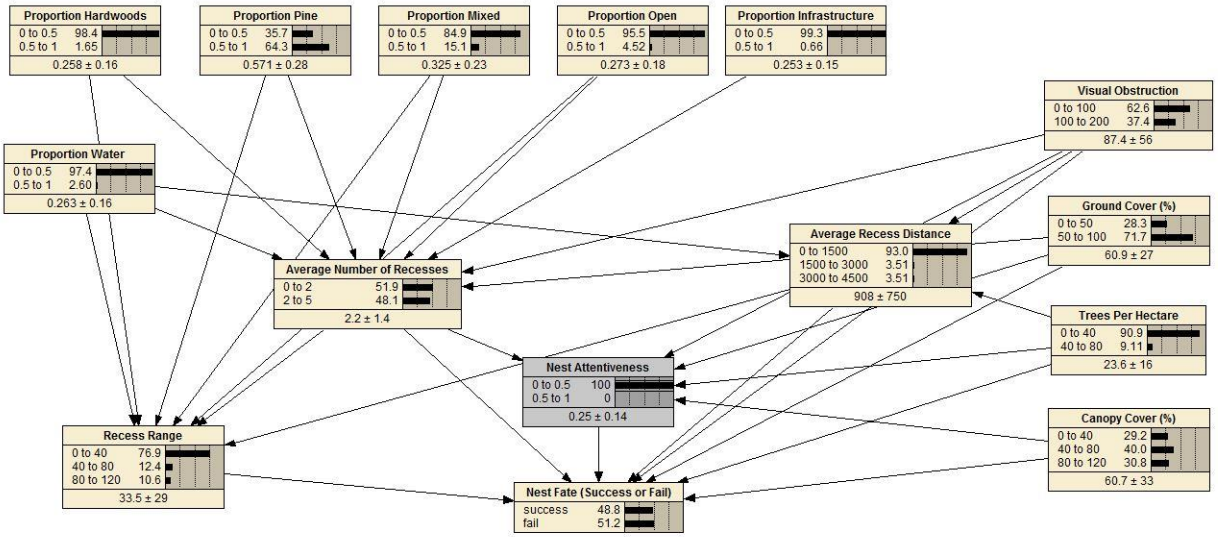

Figure 3.6. Influence of lower nest attentiveness on the casual web and how it positively influenced nest fate.

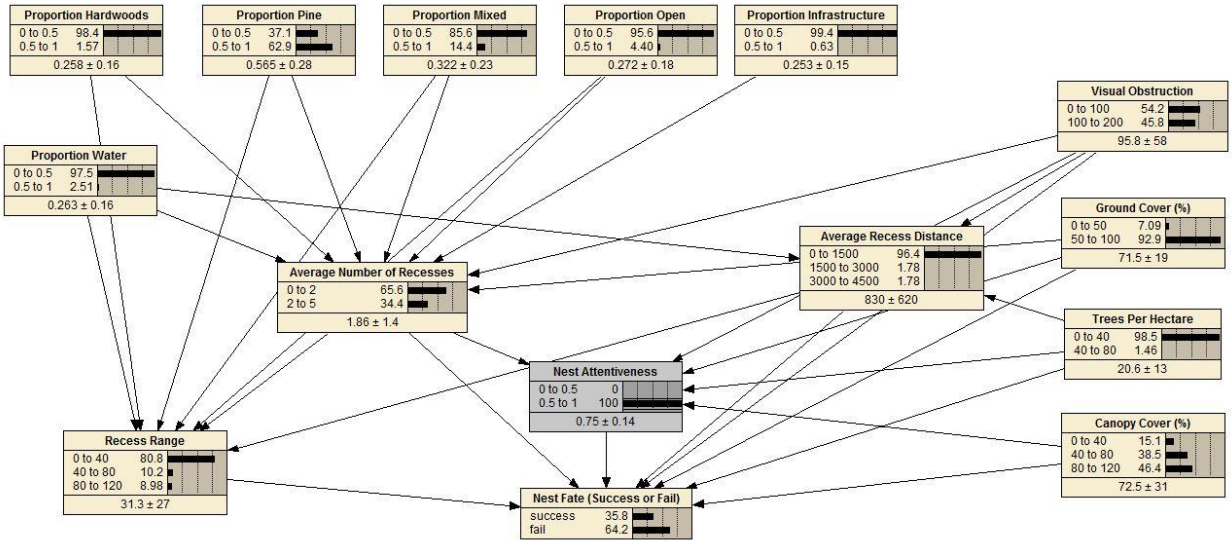

Figure 3.7. Influence of higher nest attentiveness on the causal web and how it negatively influence nest fate.

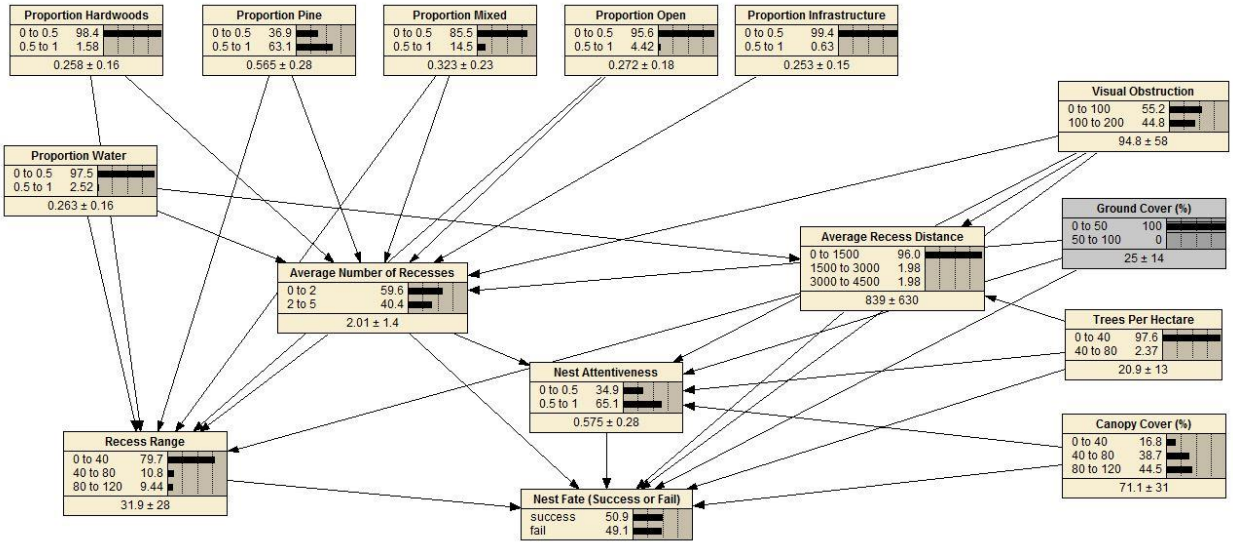

Figure 3.8. Influence of lower percentage of ground cover on the casual web and how it positively influenced nest fate.

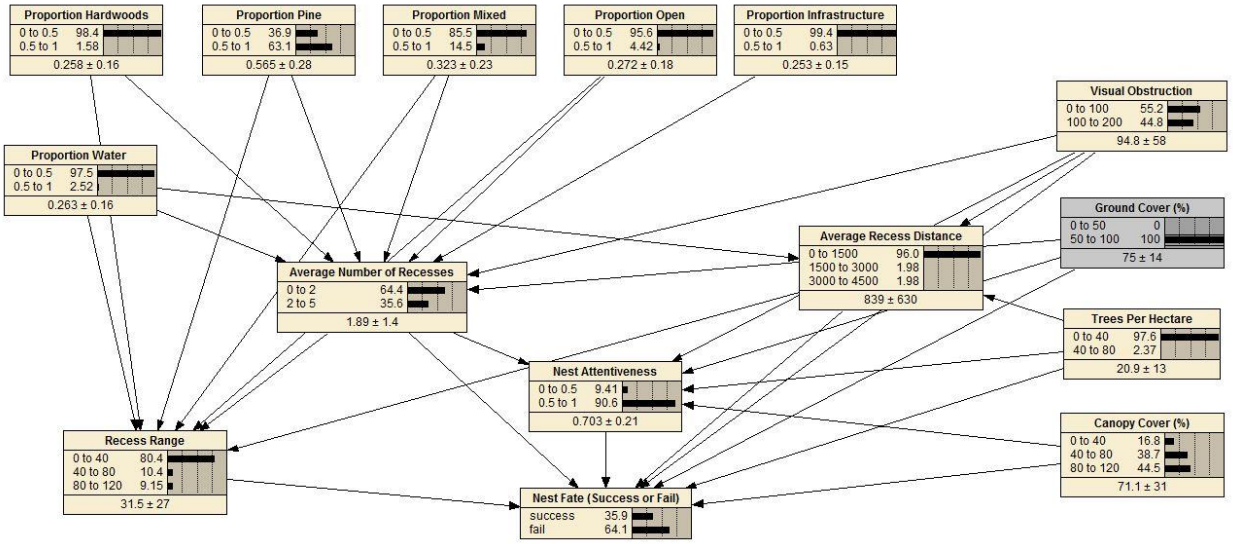

Figure 3.9. Influence of higher percentage of ground cover on the causal web and how it negatively influenced nest fate.

Recess range and nest attentiveness both had causal relationships via other variables within the network. Recess range size increased with decreased percentage of mixed pine-hardwood in the range (0–50%, variance of belief = 0.00969), increased average recess distance which influenced size (1500 m–4500 m, variance of belief = 0.00467), increased percentage of open landscape within the range (50–100%, variance of belief = 0.00322). Nest attentiveness decreased with

lower percentages of ground cover (0–50%, variance of belief = 0.00565), more trees per hectare (40–80 per ha, variance of belief = 0.00276), and moderate percentage of canopy cover (40–80%, variance of belief = 0.00188).

3.5. Discussion

Biological systems function via multiple, often competing relationships that analytical methods fail to recognize, invalid assumptions and predictions based on single model characteristics (Lebreton and Colbert 1991) leading to incomplete views of causality within a system (Carpenter 1996). By using a graphical causal network, I identified influential variables within my system, quantify the relative measure of importance for each system parameter, and directly describe biological causality linking behavioral activities, vegetation characteristics, and landscape attributes relative to the influence on nest fate. Within this vein, my results indicated that larger recess ranges, tied to increased movements off the nest site, had the most significant positive impact on nest success (positive change of 16.6%; see chapter 1). However, incubation range size was driven by the percentages of mixed pine-hardwood availability, increased average recess distances, and increased percentages of open habitat within the recess range. I found that nest success was also influenced by nest attentiveness while variation in nest attentiveness was driven by lower percentages of ground cover, higher trees per hectare, and moderate percentages of canopy cover. My results differ from nest attentiveness on shorebird species where individuals who made 17% fewer recesses during incubation had a higher chance of nest success (Smith et al. 2012). However, greater sage–grouse spent more time away from the nest when in situations of increased predator abundance leading to increased nest success (Coates and Delehantry 2008). For many avian species, individuals that choose to maximize individual survival over

reproduction have been found to reduce nest attentiveness in systems with increased predation risk (Cerencl et al. 2011, Behrens et al. 2019) which is consistent with my results in Chapter 1.

Causality between biological parameters is often based on knowledge from other research, typically described in discussion sections of papers but rarely outlined analytically. My graphical causal model supports the logic that multiple inputs, some of which provide conflicting predictions in the literature, are influencing nest fate. A suite of published results has increased our understanding of the wild turkey's reproductive system, however, my approach allows for inclusion and identification of potential interactions that have historically be unaddressed because they are causally, but not directly, linked to nest fate. For instance, Yeldell et al. (2017a), found ground cover was a driver of nest site selection but was not relevant to prediction of nest survival. My model, which found that ground cover impacts both incubation range size and nest attentiveness, provides evidence of an indirect, but no less important, linkage of ground cover on nest fate. Thus, my model allows for data on topics like behavior to be hierarchically incorporated, rather than strictly viewing nest survival as a linear function of vegetation as historically conducted (Byrne and Chamberlain 2013, Conley et al. 2015, Streich et al. 2015, Yeldell et al. 2017a, Wood et al. 2018).

Often, researchers make assumptions based on results previous studies and do not evaluate causality between system parameters in a biologically relevant framework. My approach shows that linkages within complex system may work in concert relative to nest fate. Both identification and testing of biologically relevant linkages can be conducted using graphical models to evaluate relationships between different inputs (Marcot et al. 2001) or to support conservation decisions (Borsuk et al. 2004, McNay et al. 2006, Bashari et al. 2008, MacPherson et al. 2018). My model indicates that behavioral activities could underlie the relative importance

of local scale vegetation metrics (Streich et al. 2015, Conley et al. 2015, Yeldell et al. 2017), yet those characteristics are significant to nest site selection but do not impact nest survival. I are not saying that single dimensional studies are invalid, but suggest that by restructuring my modeling approach around biological causality, we gain better understanding of the system as a whole. Further, the application of sensitivity analysis within the BBN allows for increased understand both the parameter of interest but also underlying parameters within the system (Marcot et al. 2001). Thus, both direct and indirect estimates of parameter sensitivity can be garnered, providing an evaluation of what measurable variables are having the most impact on both the target, and intermediate biological inputs. Using sensitivity analysis in this manner increases my knowledge of the system and allows for us to explore and identify parameters that need additional precision hence potentially refining my research questions.

Graphical decision tools such as a BBN allows researchers to incorporate expert opinion, input data from previous and recent studies, evaluate multiple causal relationships within a system, and if the models accurately depicts the biological system can identify data needs and measurements of importance (Marcot et al. 2001). Additionally, graphical causal models allow for updating of empirical data, or node/causal diagram redefinition as new system information is gathered while also providing the simplicity of the graphical model which can allow managers to easily redefine nodes, re-evaluate new relationships as new information becomes available, and evaluate what-if scenarios before potential experimental treatments to identify what input and output metrics of interest should be examined.

CHAPTER 4. CONCLUSIONS

I found that the average number of days a female wild turkey incubated a nest was 10 days, and 75% of nesting attempts failed by day 14. My estimates of nest attentiveness suggest that hens spent between 1–2 hours per day recessing away from the nest. Nest attentiveness estimates for wild turkey were lower (84%) relative to other ground nesting galliforms. I found that daily nest survival was influenced by recess behaviors, but the impact of recess behaviors was limited to those individuals who recessed more than once per day. My results suggest that for wild turkeys reduced nest attentiveness and increased recess movements may confer positive fitness consequences relative to nest survival. My results show that frequency of recesses, distance traveled during recess movements, and available resources did not differ between successful and failed nests. Conversely, females that renested and took more recesses had reduced success, which suggests that remaining on the nest as the nesting season progresses may be a more optimal strategy. Further research needs to evaluate recess behaviors at an individual level to understand different strategies throughout species.

I found using conceptual models provided a new avenue to explore biologically relevant interactions within the system. I identified influential variables within my system, quantify the relative measure of importance for each system parameter, and directly describe biological causality linking behavioral activities, vegetation characteristics, and landscape attributes relative to the influence on nest fate. My results suggest that behavioral factors in combination with vegetation characteristics influence nest fate. Larger incubation ranges had the most significant positive impact on nest success. However, incubation range size was driven by the percentages of mixed pine-hardwood availability, increased average recess distances, and increased percentages of open habitat within the recess range. I found that nest success was also influenced

by nest attentiveness while variation in nest attentiveness was driven by lower percentages of ground cover, higher trees per hectare, and moderate percentages of canopy cover. I found graphical models are a powerful tool for researchers and managers to incorporate empirical data and look at causality within the system.

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APPENDIX INCUBATION BEHAVIOR TABLES AND FIGURES

Table A.1. Model coefficients from the best fitting candidate model S (No. recess movements + Recess distance + No. recess movements * Recess distance) used to examine the effect of frequency of daily recess movement intensity and distance of daily recess movements on daily nest survival of Eastern wild turkeys in the southeastern United States 2014–2017.

Coefficients	β	SE	LCL	UCL
Intercept	3.02	0.137	2.751	3.291
No. Recess Movements	-0.31	0.094	-0.503	-0.134
Recess Distance	-0.005	0.001	-0.008	-0.002
No. recess movements * Recess distance	0.006	0.001	0.003	0.008

Figure A.1. Proportion of vegetation classes making up the 50%, 75%, 99% utilizations distributions by nesting attempts for Eastern wild turkey (*Meleagris gallopavo silvestris*) across all study sites.

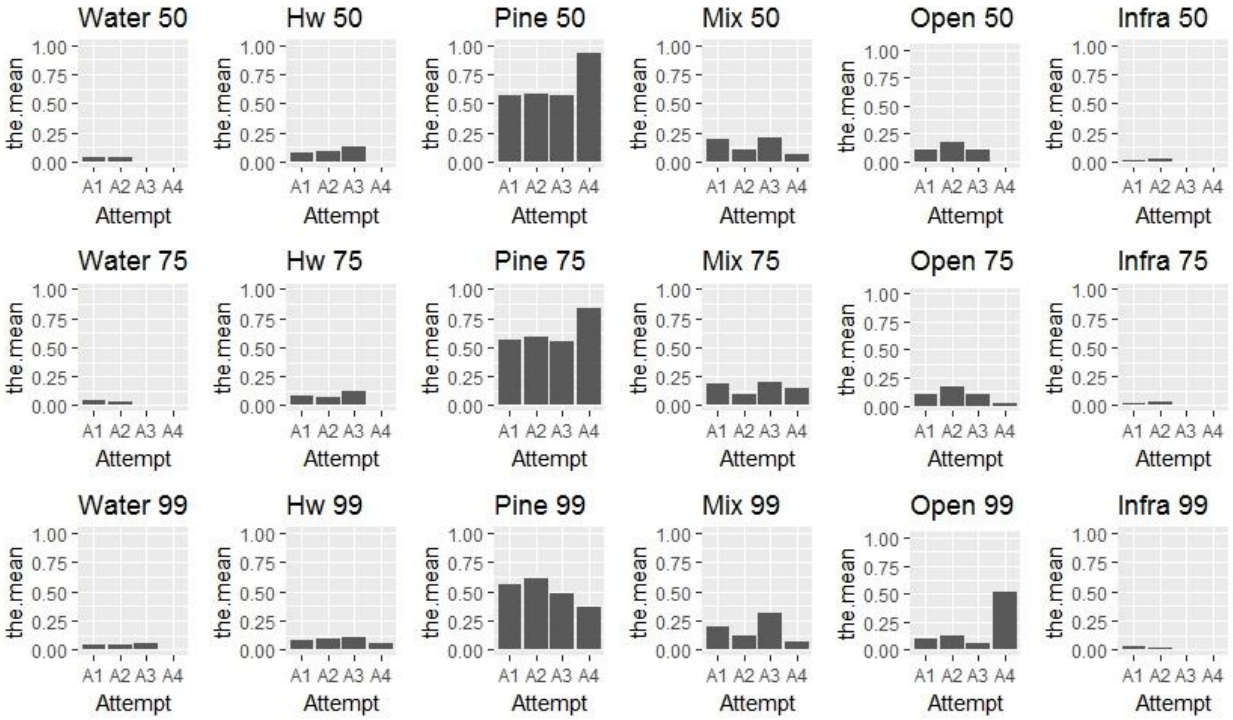


Figure A.2. Proportion of vegetation classes making up the 50%, 75%, 99% utilizations distributions by nest fate (0 = failed attempt, 1 = successful attempt) for Eastern wild turkey (*Meleagris gallopavo silvestris*) across all study sites.

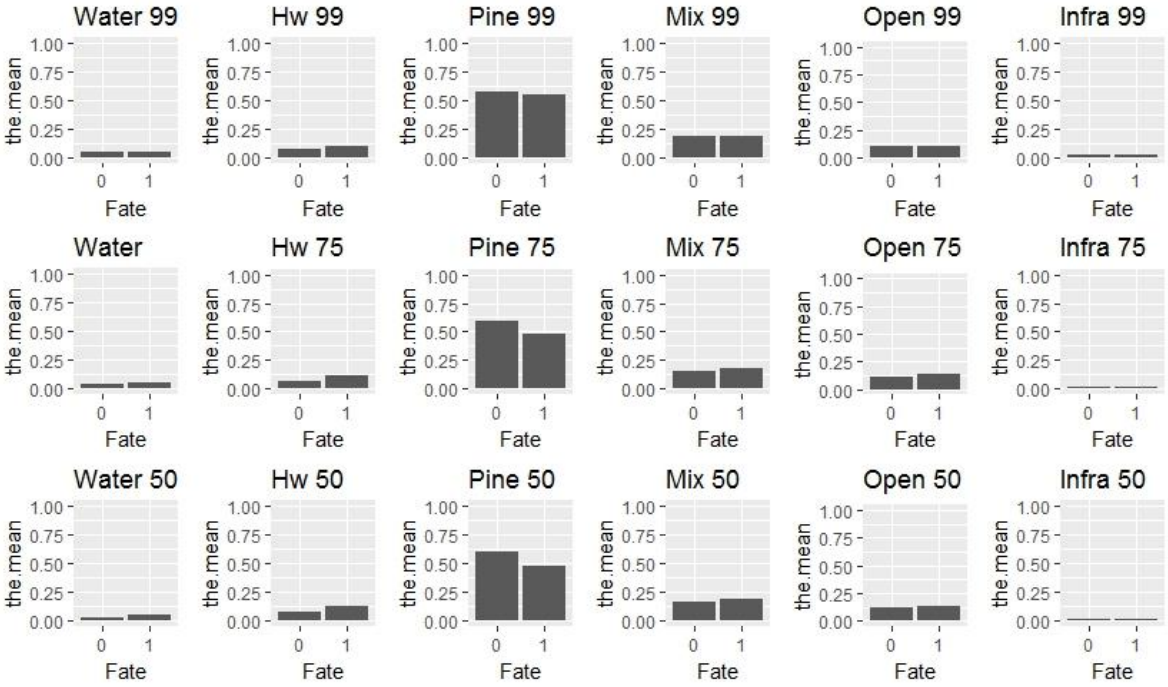
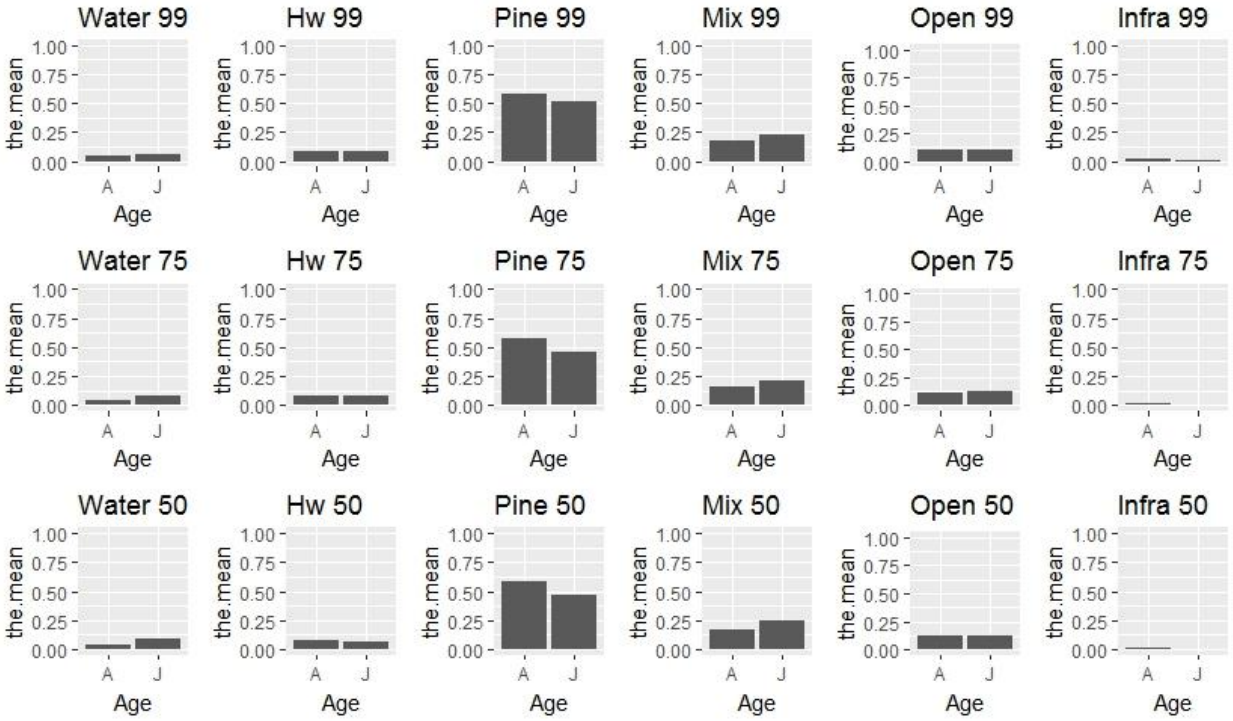


Figure A.3. Proportion of vegetation classes making up the 50%, 75%, 99% utilizations distributions by age (A = adult, J = juvenile) for Eastern wild turkey (*Meleagris gallopavo silvestris*) across all study sites.



VITA

Nicholas Wilson Bakner, born in Chambersburg, Pennsylvania in 1991, graduated from Pennsylvania State University. After graduating college he worked the Pennsylvania Game Commission, Ducks Unlimited, and Virginia Department of Game and Inland Fisheries to further is field experience with gamebirds. After gaining experience in the field, he decided to pursue a Master's degree at the School of Renewable Natural Resources at Louisiana State University. Upon completions of his master's degree, he will begin to work for Florida Fish and Wildlife Conservation Commission as their Assistant Wild Turkey Program Coordinator.